US011008900B2

(12) United States Patent
Liskar et al.

(10) Patent No.: US 11,008,900 B2
(45) Date of Patent: May 18, 2021

(54) **SLIDING CONTACT FOR ELECTRICALLY ACTUATED ROCKER ARM**

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(73) Assignee: **Eaton Intelligent Power Limited**, Dublin (IE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/893,823**

(22) Filed: **Jun. 5, 2020**

(65) **Prior Publication Data**

US 2020/0300129 A1 Sep. 24, 2020

Related U.S. Application Data

(60) Division of application No. 16/460,886, filed on Jul. 2, 2019, now Pat. No. 10,731,518, which is a division of application No. 15/863,901, filed on Jan. 6, 2018, now Pat. No. 10,358,951, which is a continuation-in-part of application No. 15/503,458, filed on Feb. 13, 2017, now Pat. No. 10,180,089, and a continuation-in-part of application No. PCT/US2016/063730, filed on Nov. 24, 2016.

(Continued)

(51) **Int. Cl.**
F01L 1/18 (2006.01)
F01L 1/22 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F01L 1/22*** (2013.01); ***F01L 1/053*** (2013.01); ***F01L 1/181*** (2013.01); ***F01L 1/185*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC ... F01L 1/185; F01L 2001/186; F01L 1/2405; F01L 1/46; F01L 2009/0403;
(Continued)

(56) **References Cited**

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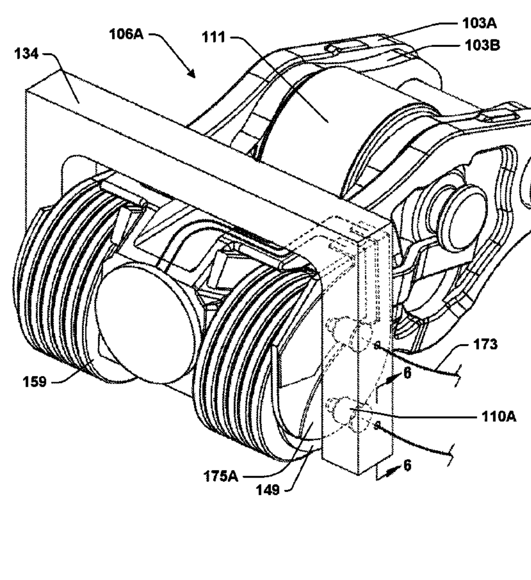
* cited by examiner

Primary Examiner — Jorge L Leon, Jr.
(74) *Attorney, Agent, or Firm* — Paul V. Keller

(57) **ABSTRACT**

A valvetrain for an internal combustion engine of the type that has a combustion chamber, a moveable valve having a seat formed in the combustion chamber, and a camshaft includes a rocker arm assembly, a pivot providing a fulcrum for a rocker arm of the rocker arm assembly, and a latch assembly. An electrical device mounted to the rocker arm assembly receives power or communicates through a circuit that includes an electrical connection formed by abutment between surfaces of two distinct parts. The rocker arm assembly is operative to move one of the two abutting surfaces relative to the other in response to actuation of the cam follower. Forming an electrical connection through abutting surfaces that are free to undergo relative motion may reduce or eliminate the need to run wires to a mobile portion of the rocker arm assembly.

20 Claims, 35 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/503,303, filed on May 8, 2017, provisional application No. 62/488,747, filed on Apr. 22, 2017, provisional application No. 62/449,174, filed on Jan. 23, 2017, provisional application No. 62/305,612, filed on Mar. 9, 2016, provisional application No. 62/259,764, filed on Nov. 25, 2015.

(51) **Int. Cl.**
F01L 1/053 (2006.01)
F01L 13/00 (2006.01)
F01L 1/24 (2006.01)
F01L 3/24 (2006.01)

(52) **U.S. Cl.**
CPC ***F01L 1/2405*** (2013.01); ***F01L 3/24*** (2013.01); ***F01L 13/0005*** (2013.01); *F01L 13/0036* (2013.01); *F01L 2001/0535* (2013.01); *F01L 2001/186* (2013.01); *F01L 2013/001* (2013.01); *F01L 2013/101* (2013.01); *F01L 2201/00* (2013.01); *F01L 2305/00* (2020.05)

(58) **Field of Classification Search**
CPC F01L 2009/0421; F01L 2009/0446; F01L 2009/0448; F01L 2009/0463; F01L 13/0005; F01L 2820/031
USPC 123/90.11, 90.41, 90.43, 90.44, 90.46
See application file for complete search history.

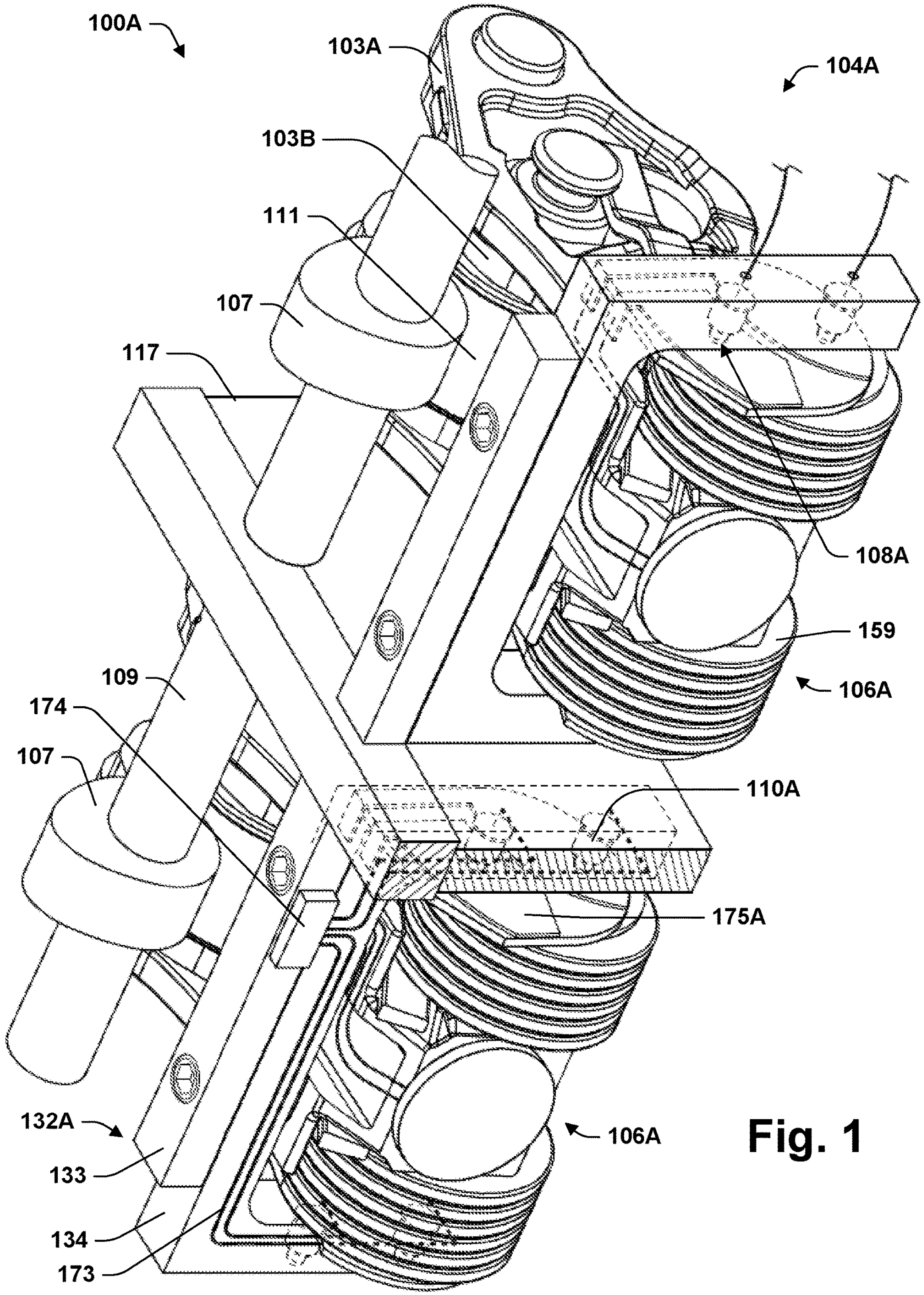

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Fig. 1

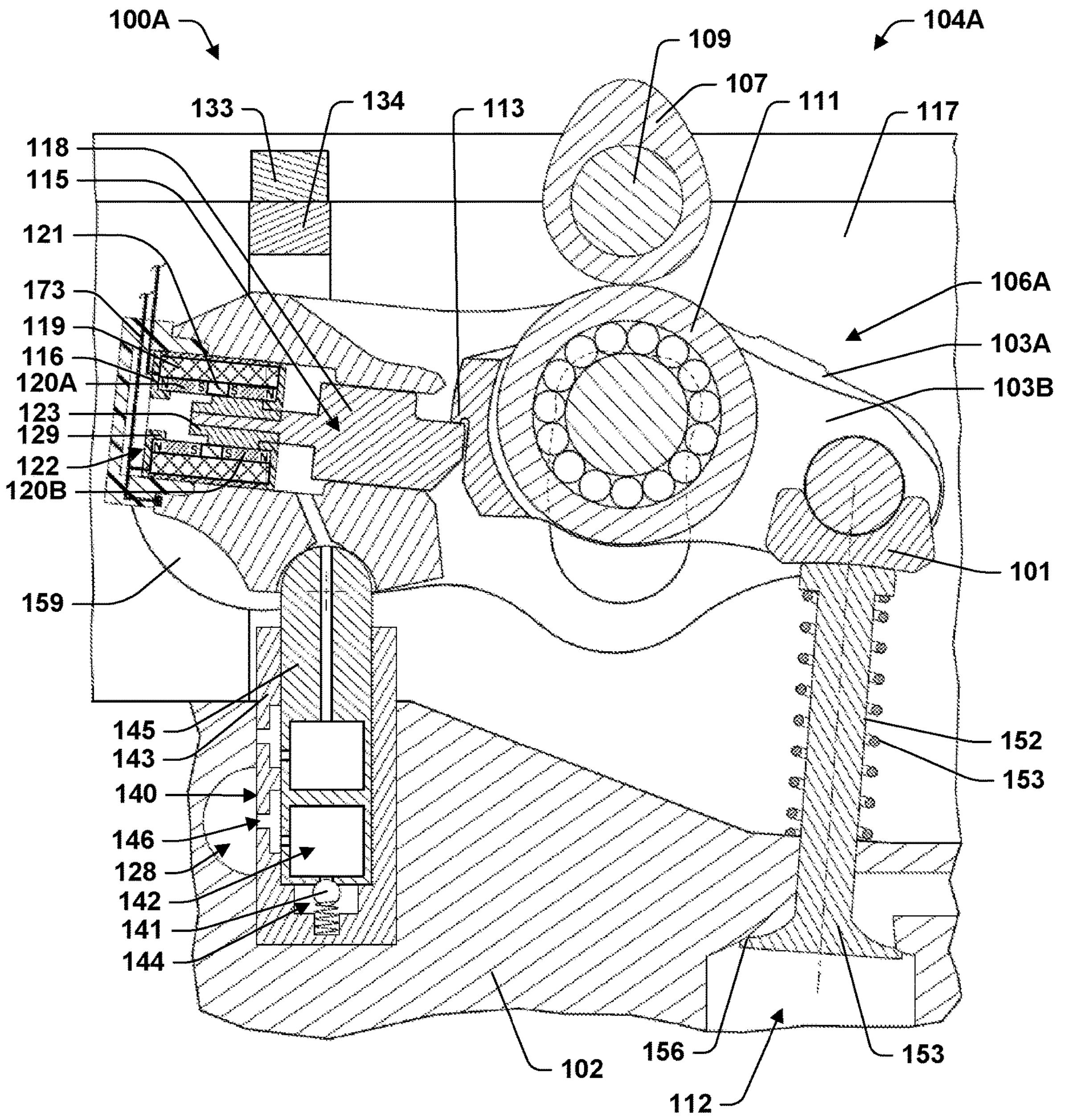
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Fig. 2

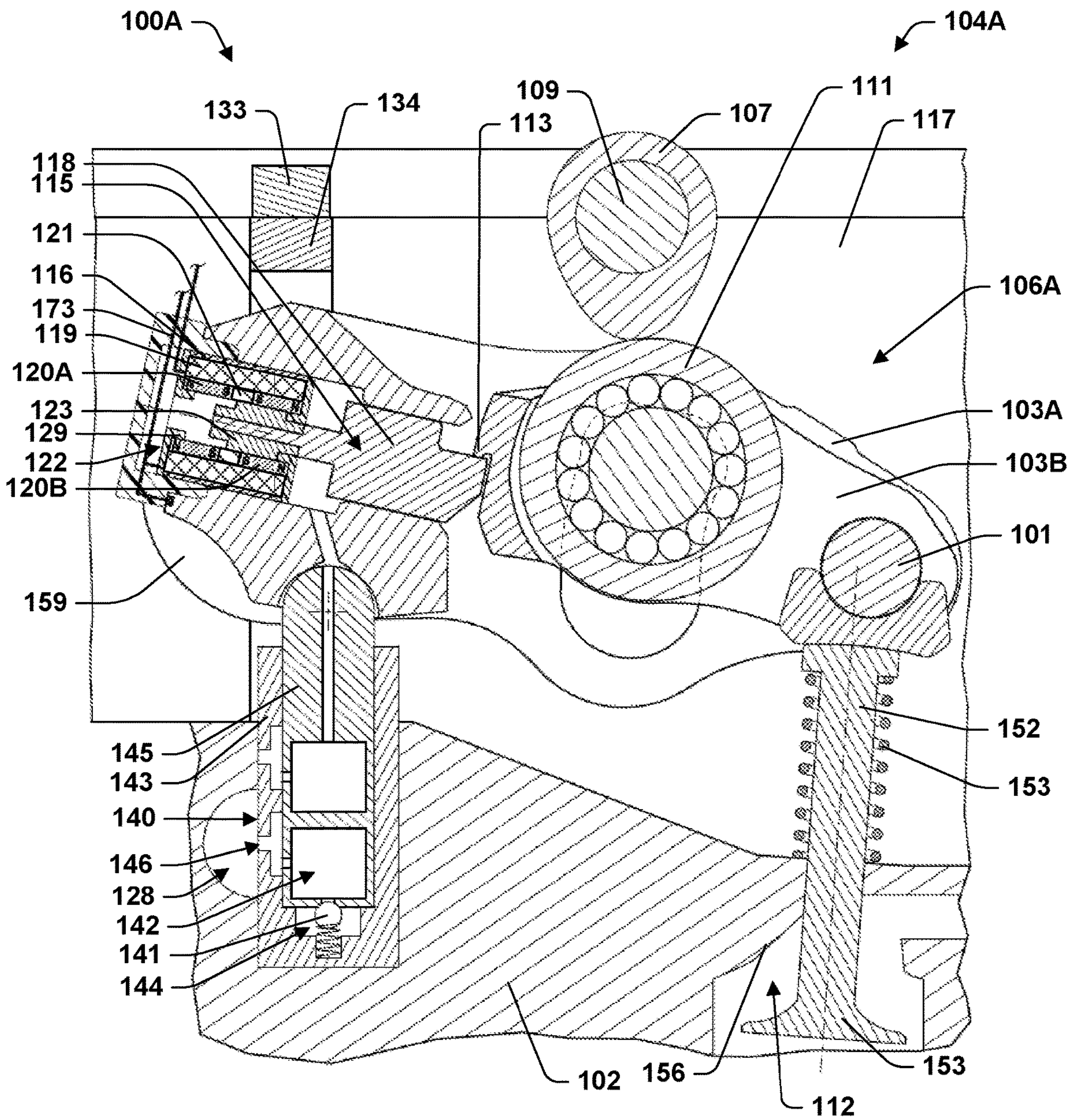
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Fig. 3

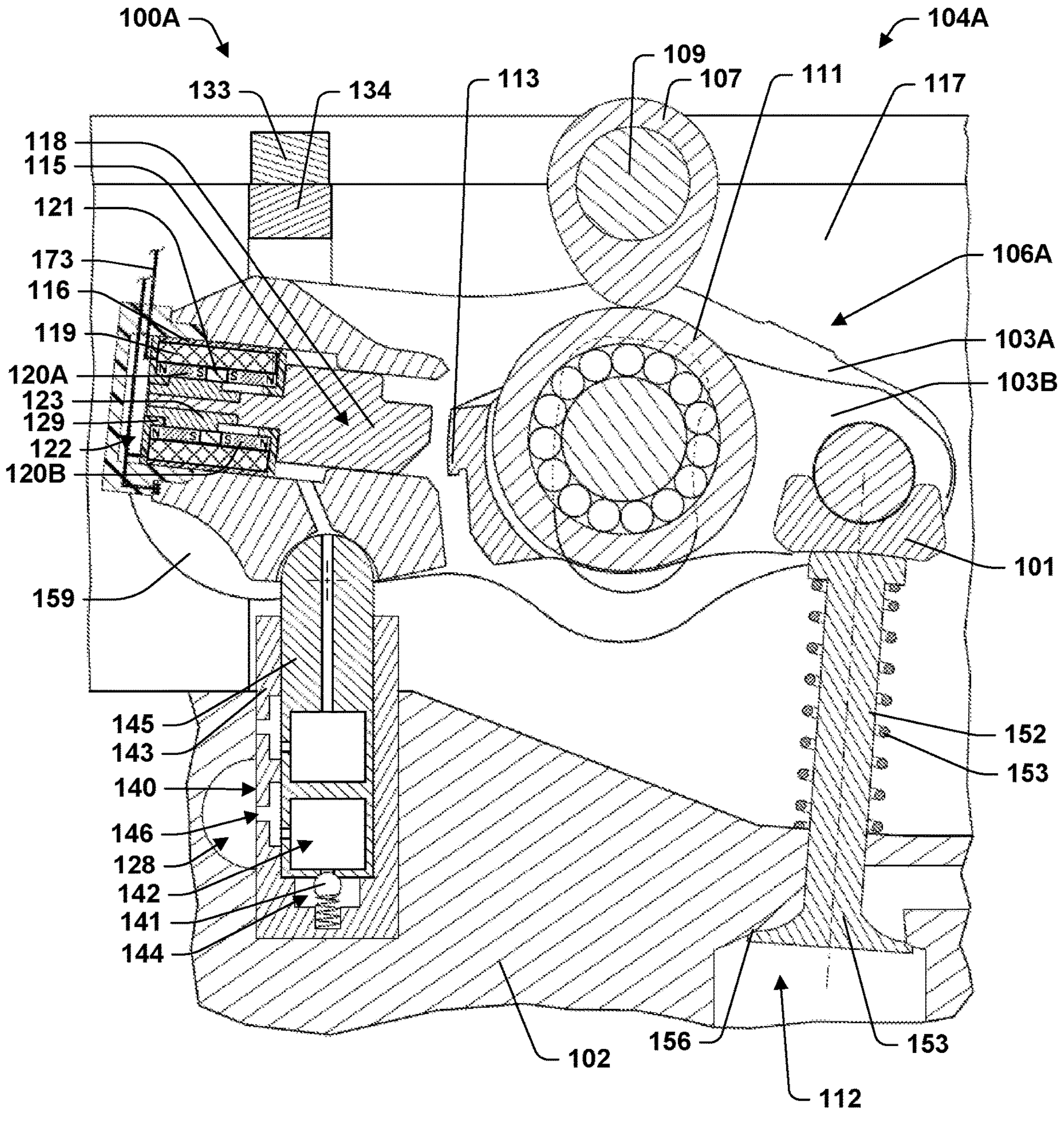
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Fig. 4

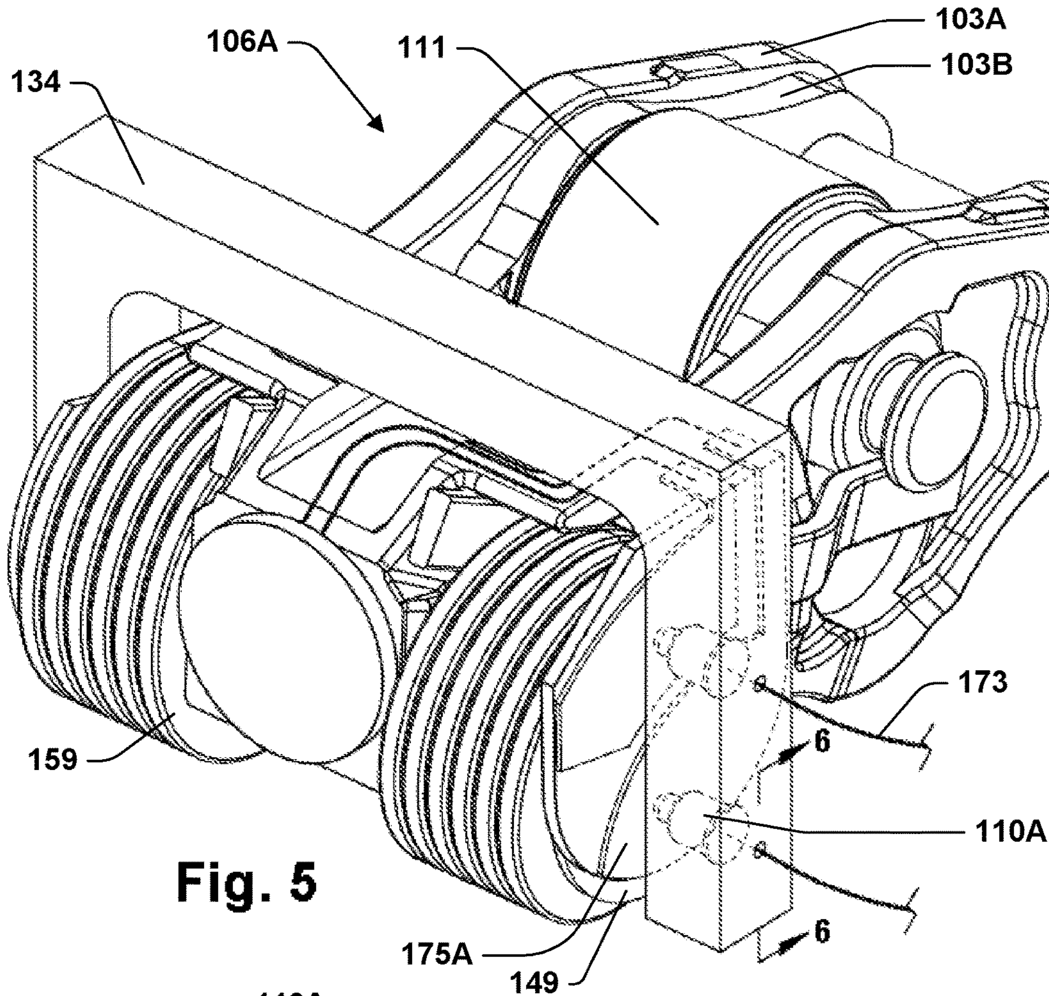
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Fig. 5

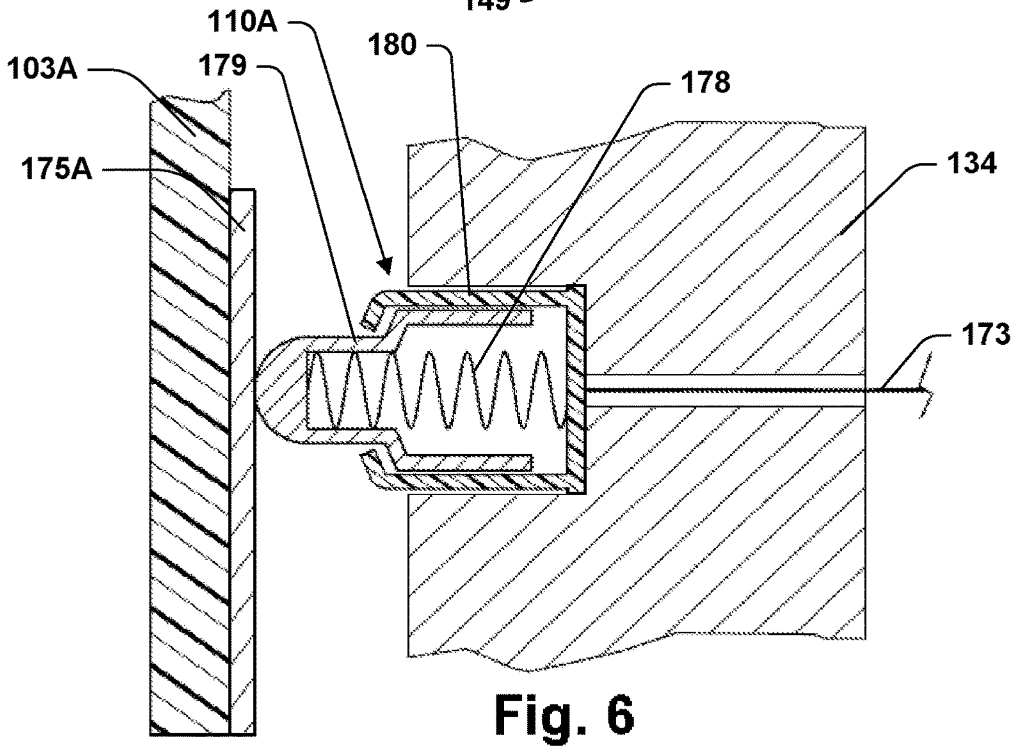
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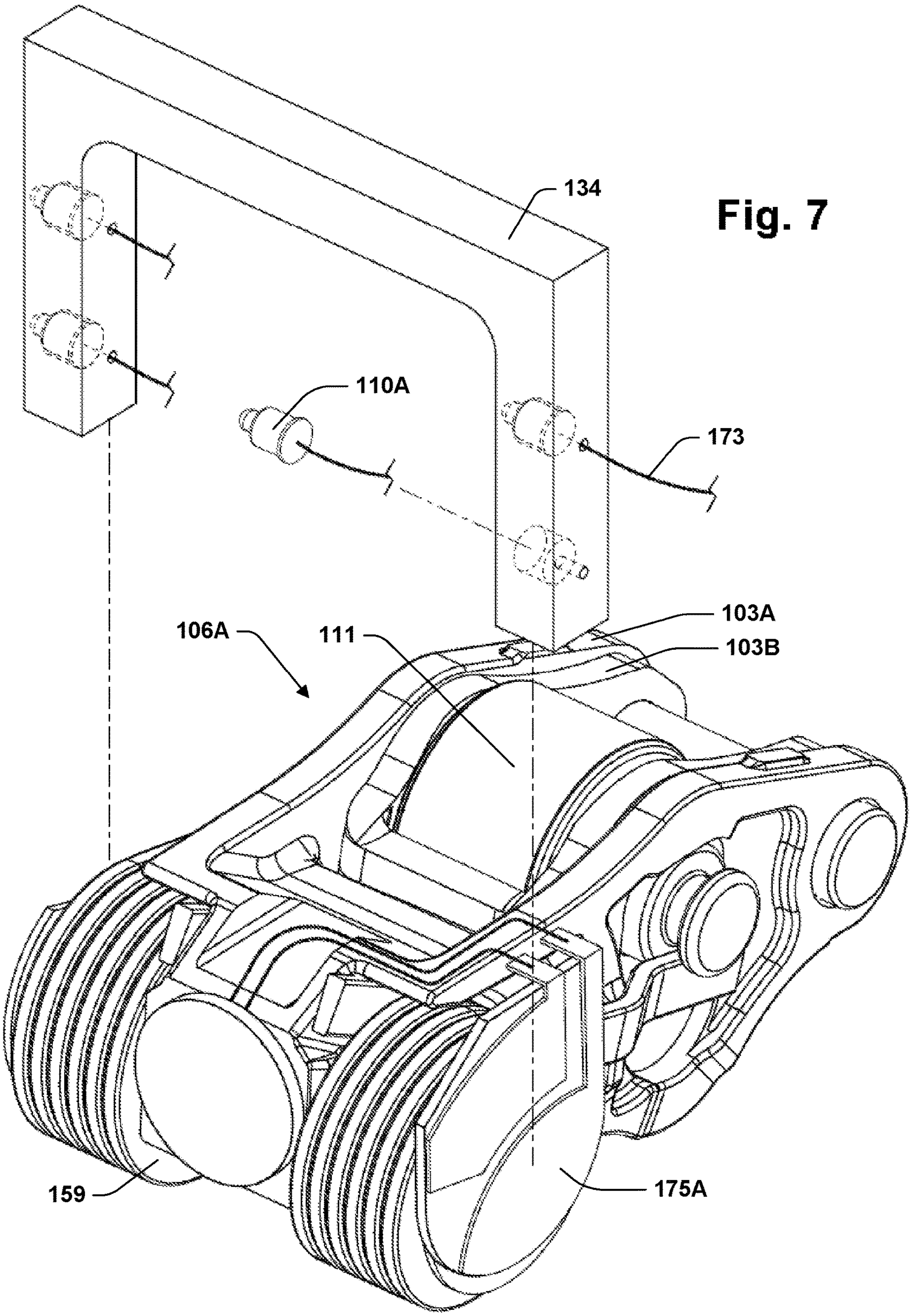
Fig. 6



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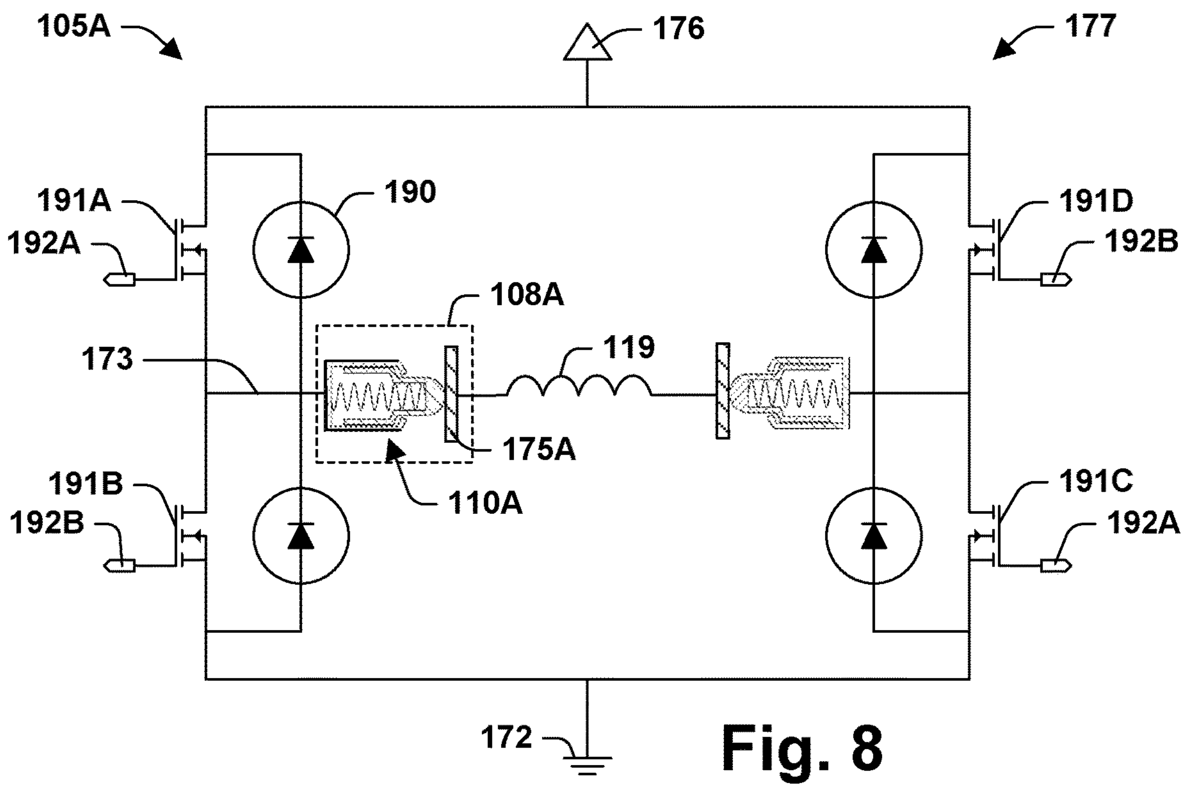
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191B
192B
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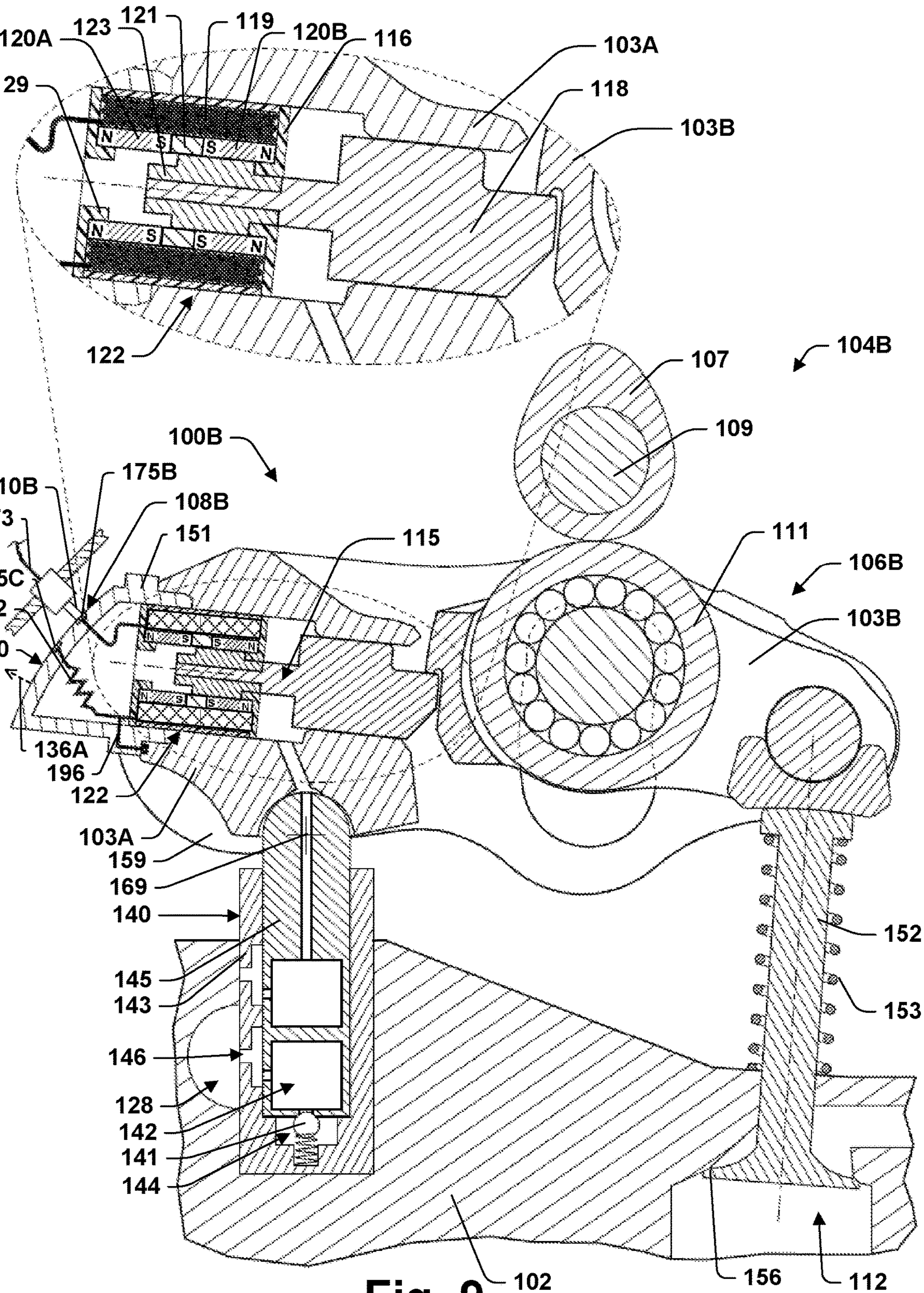
192A
172

Fig. 8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104B
107
109
100B
110B
175B
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106B
175C
103B
182
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136A
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Fig. 9

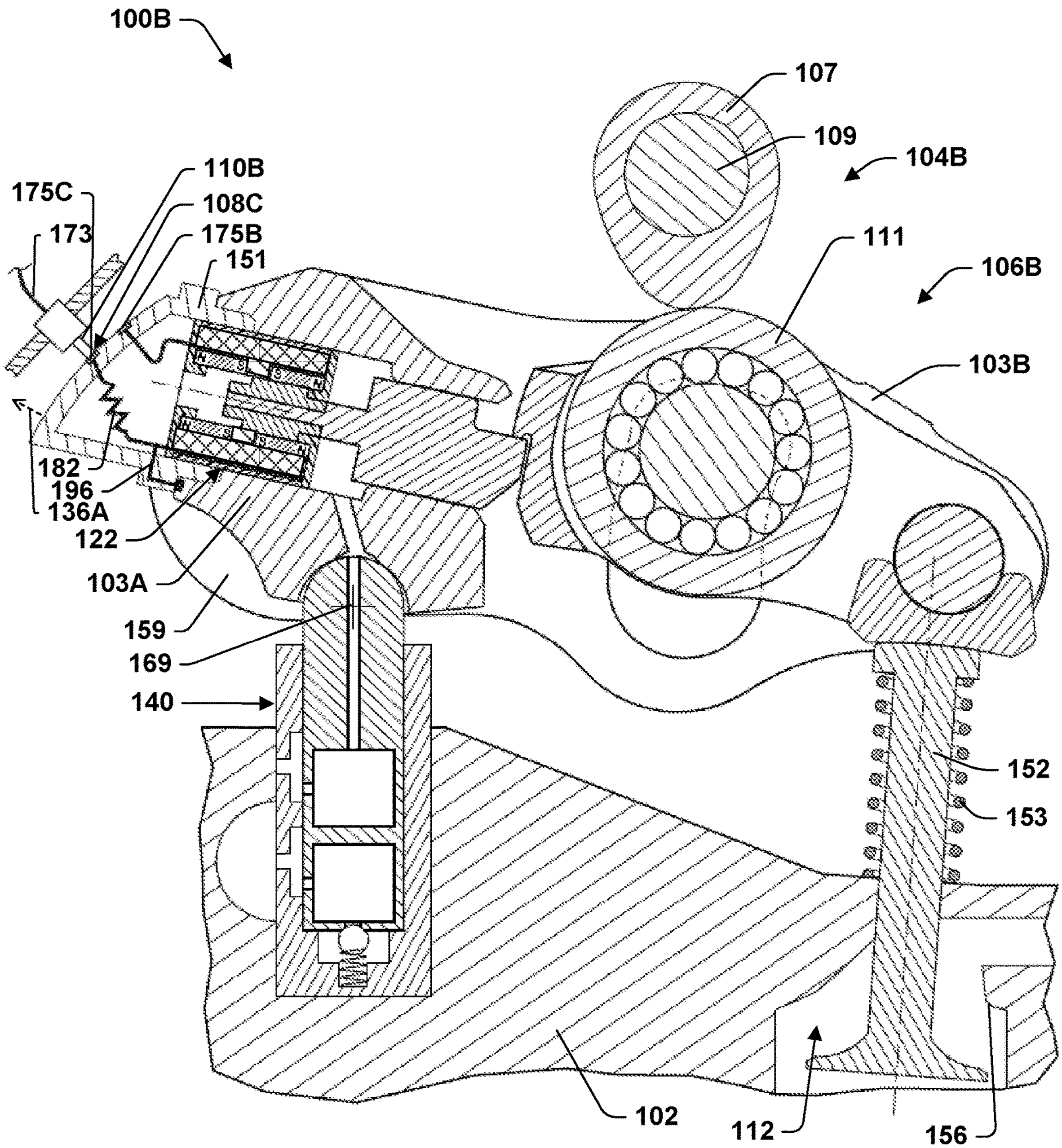

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Fig. 10

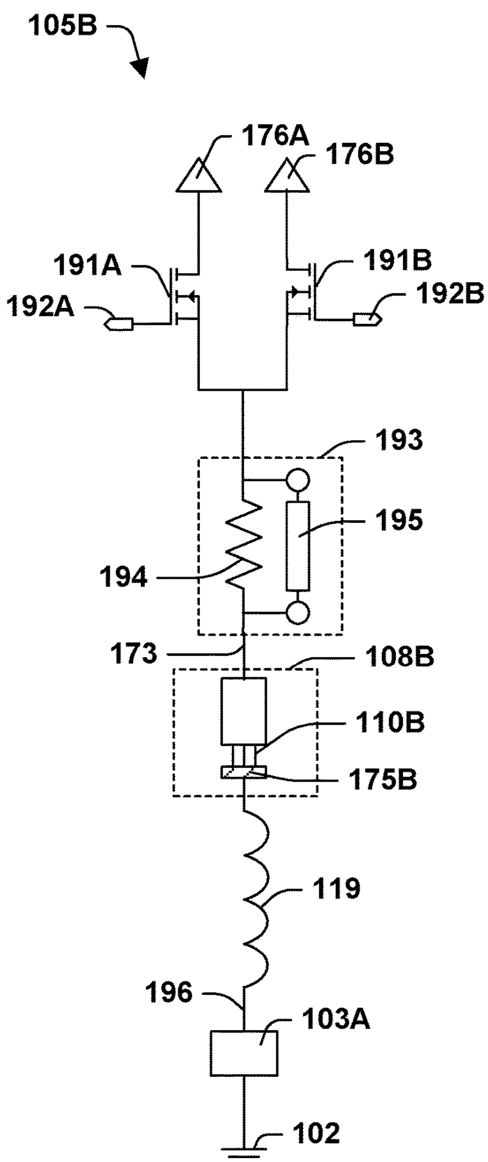

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Fig. 11

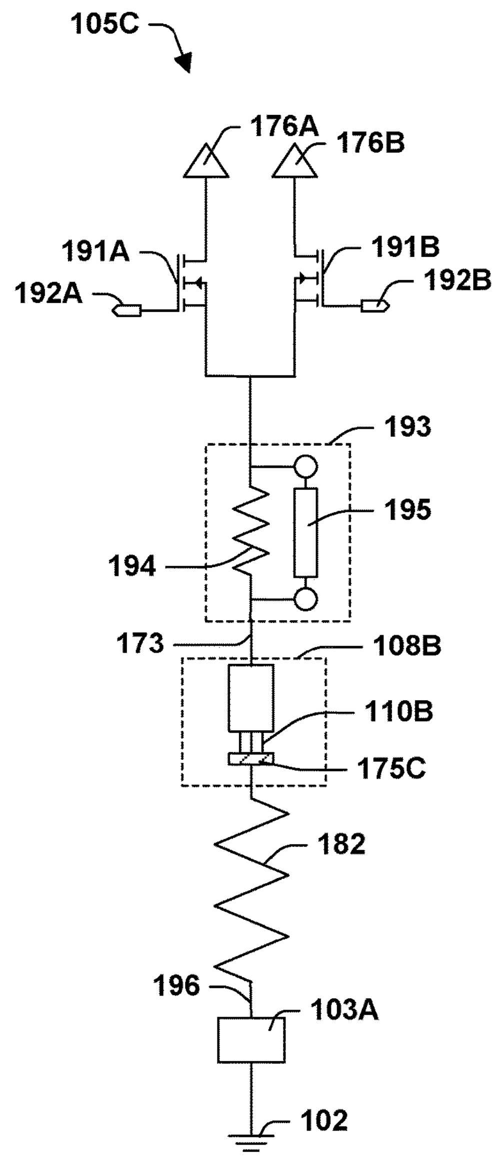

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Fig. 12

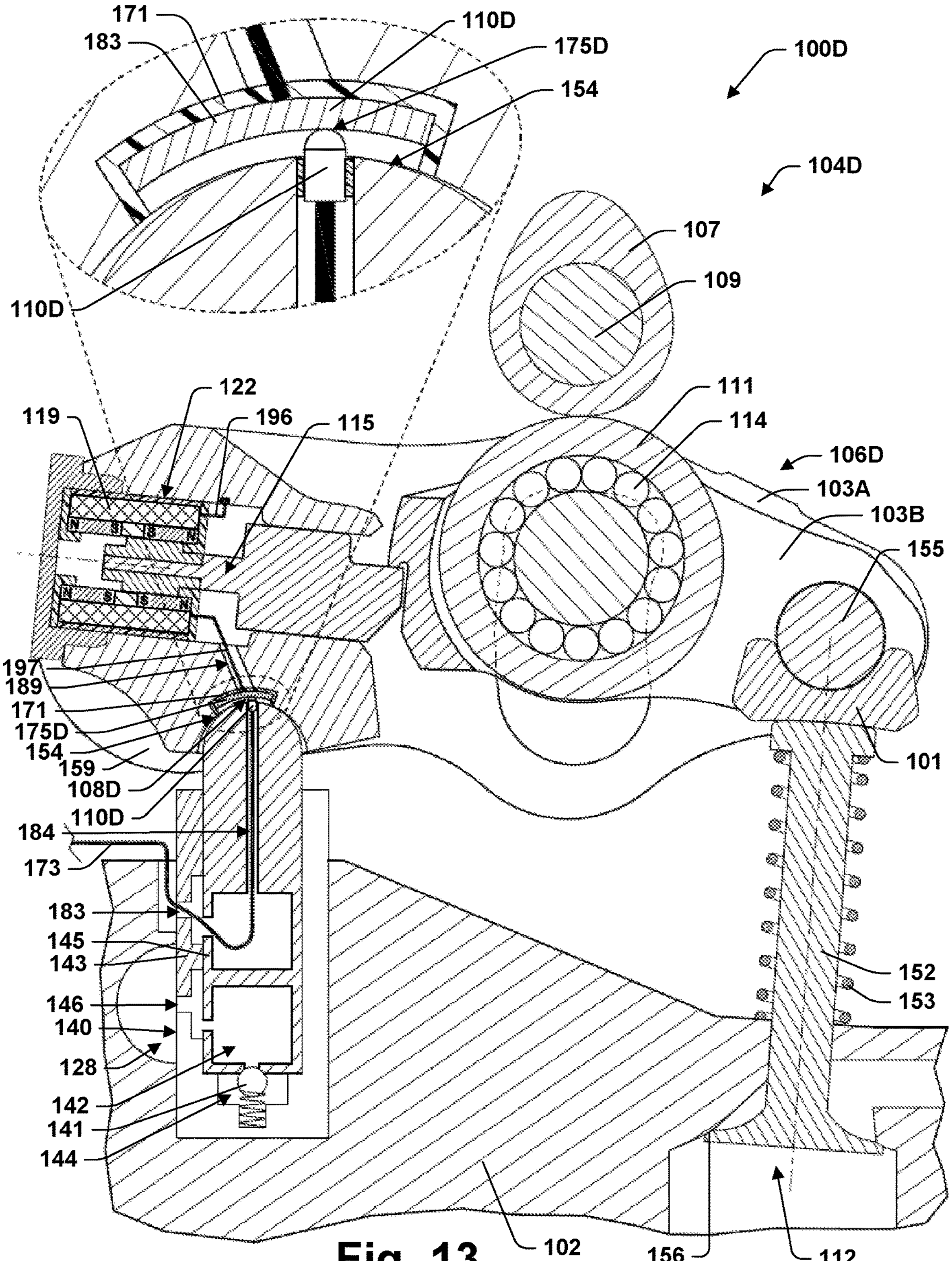
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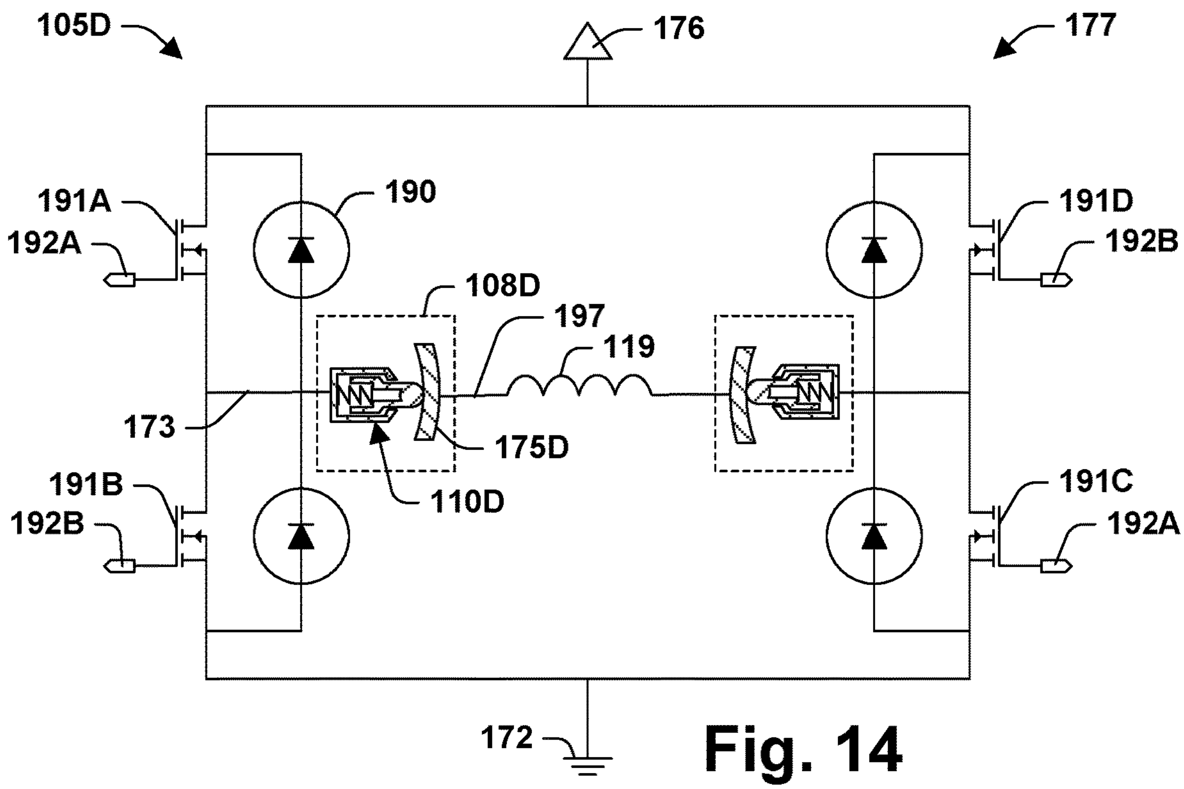
Fig. 13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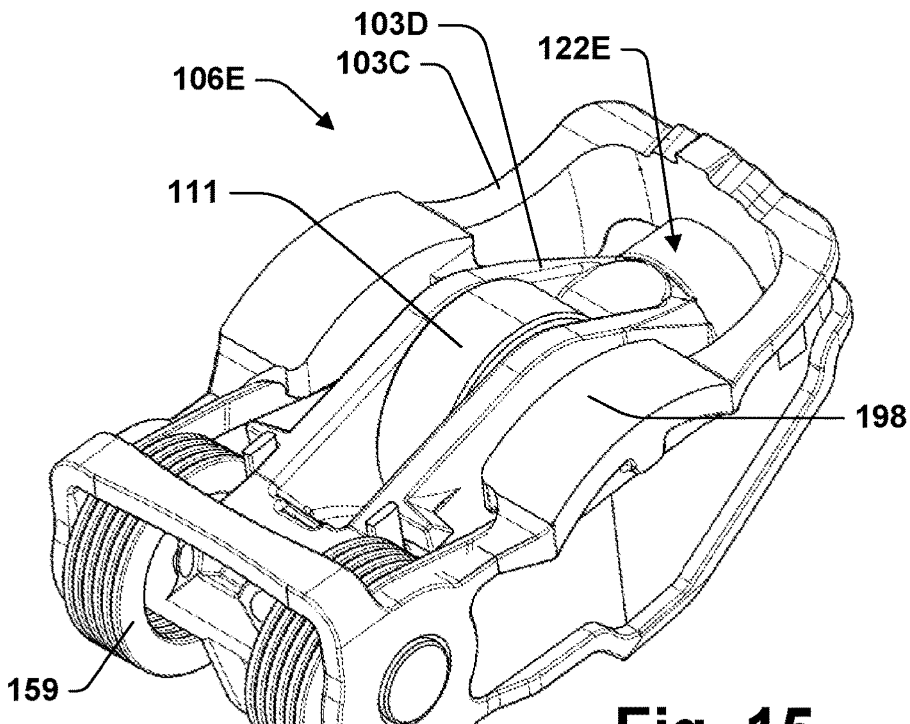
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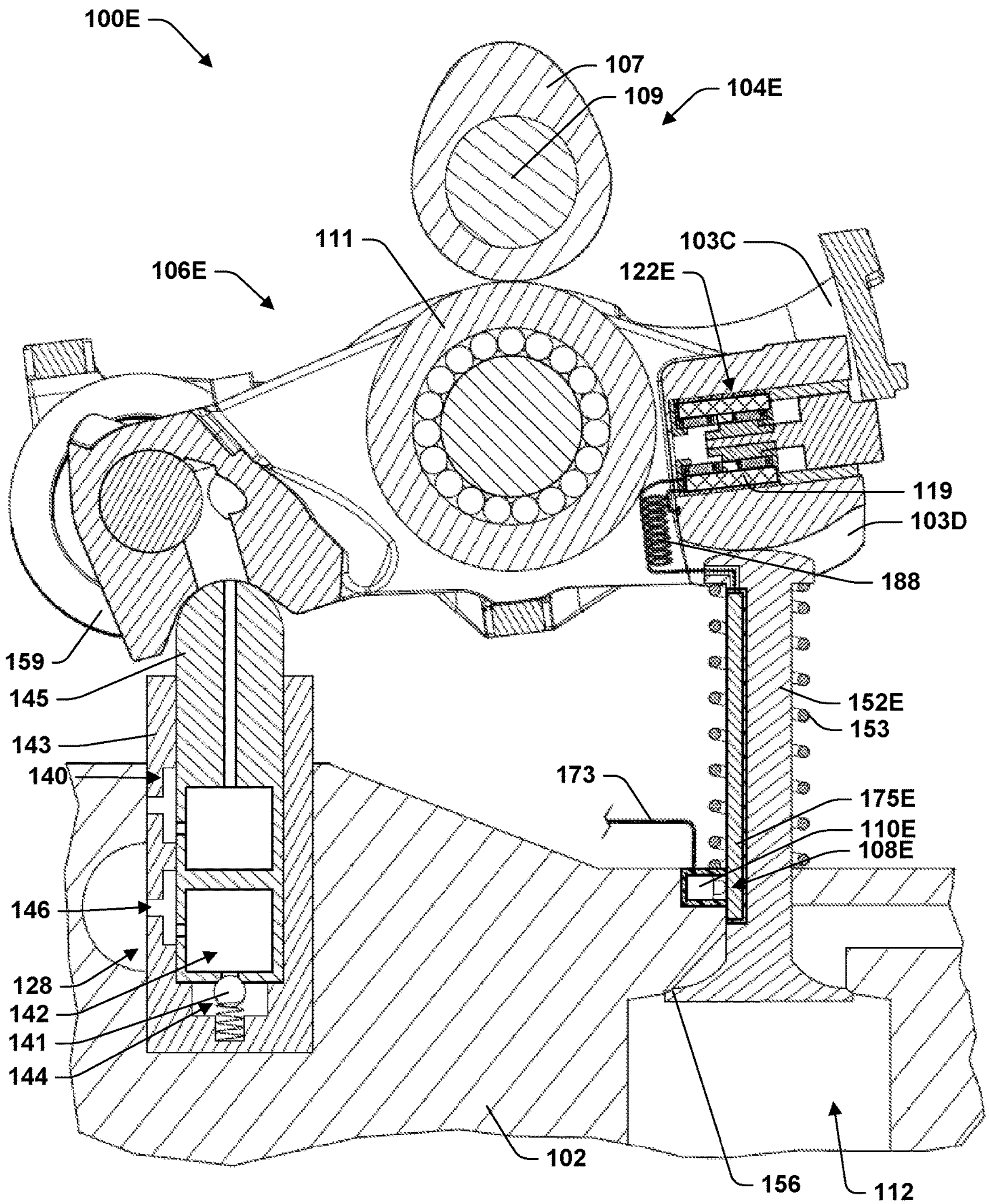
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Fig. 16

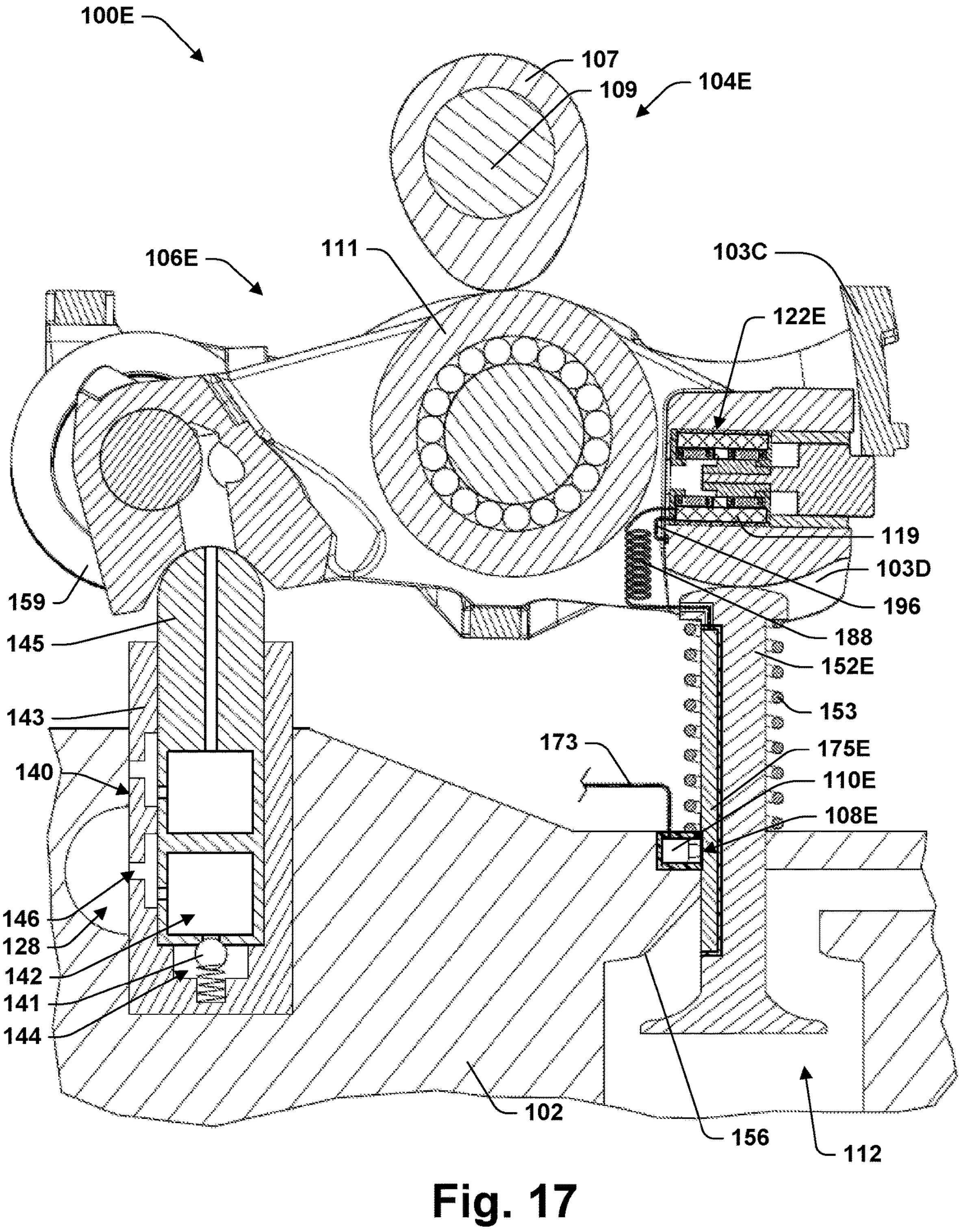
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Fig. 17

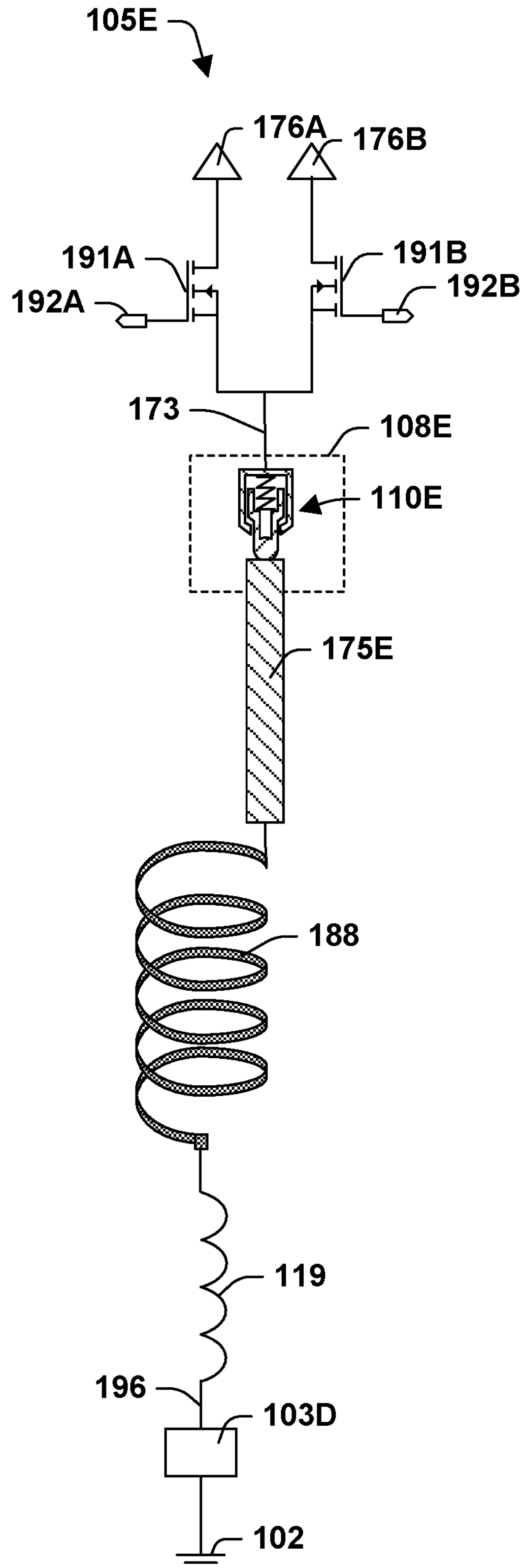
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Fig. 18

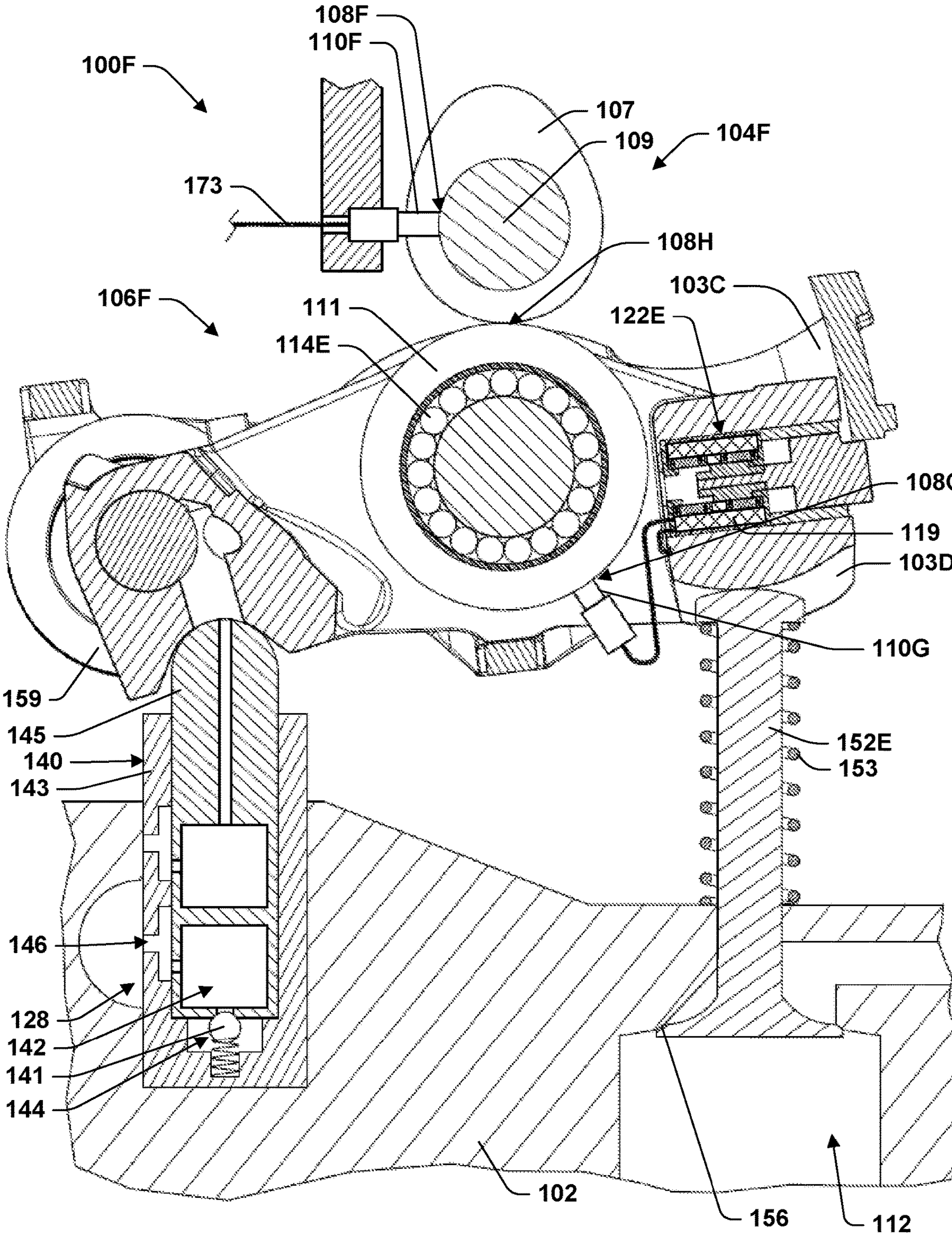

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Fig. 19

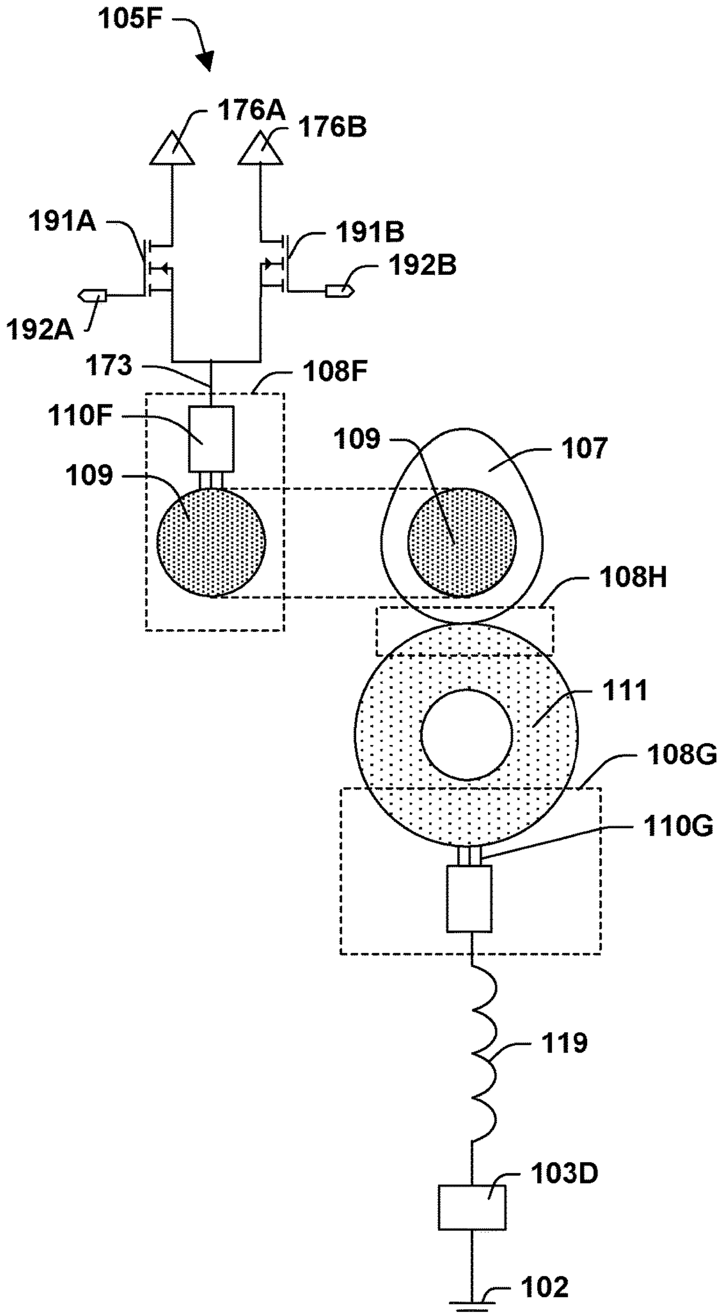
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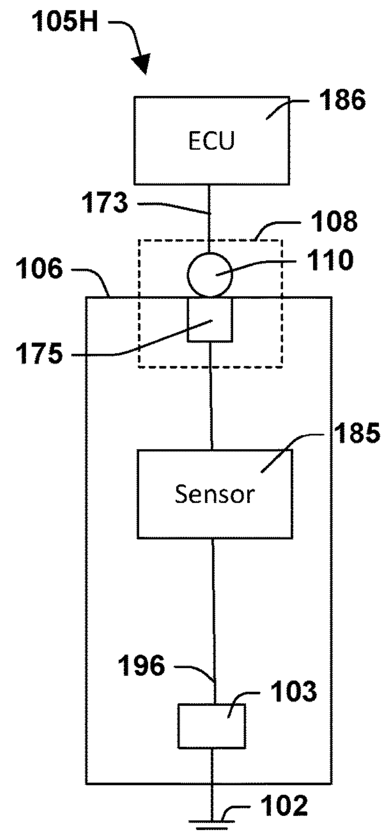
Fig. 20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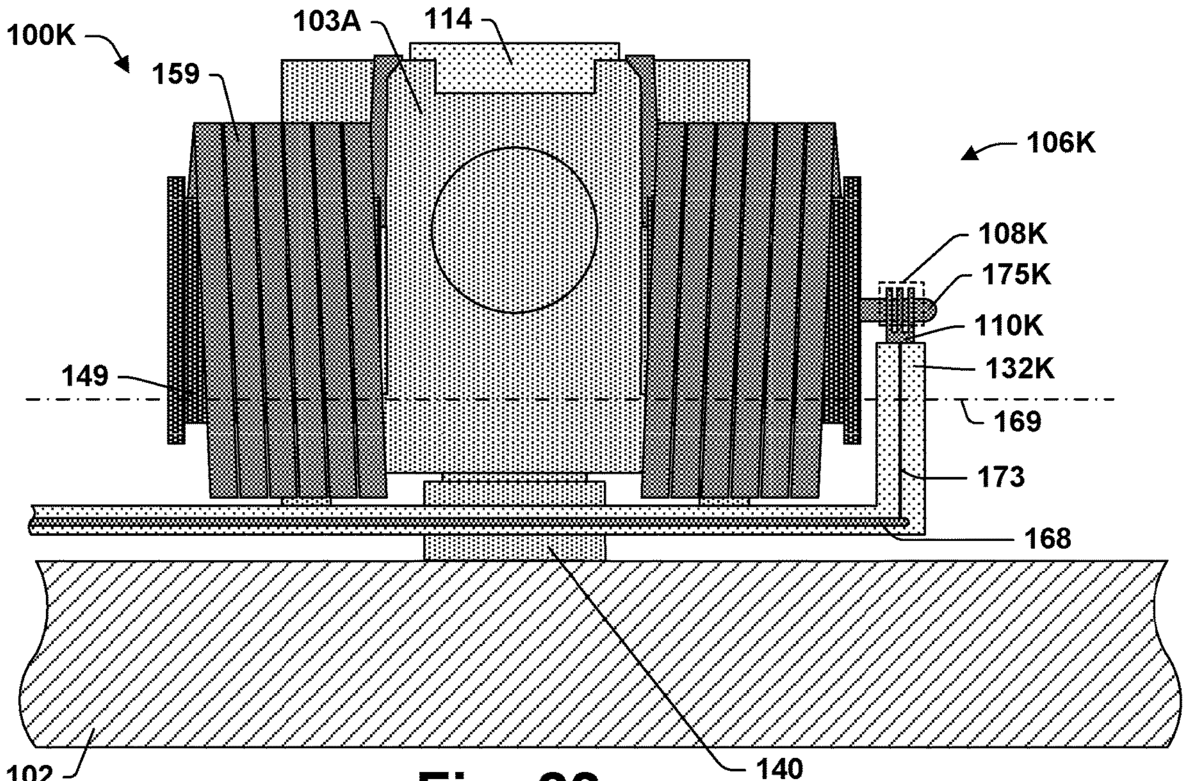
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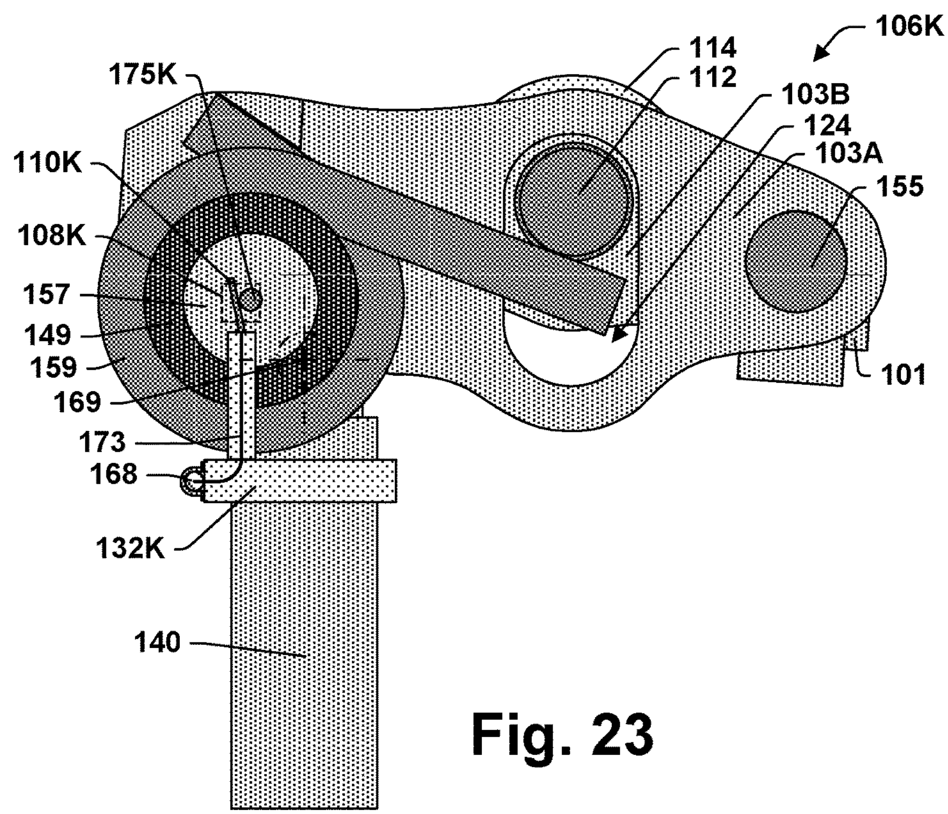
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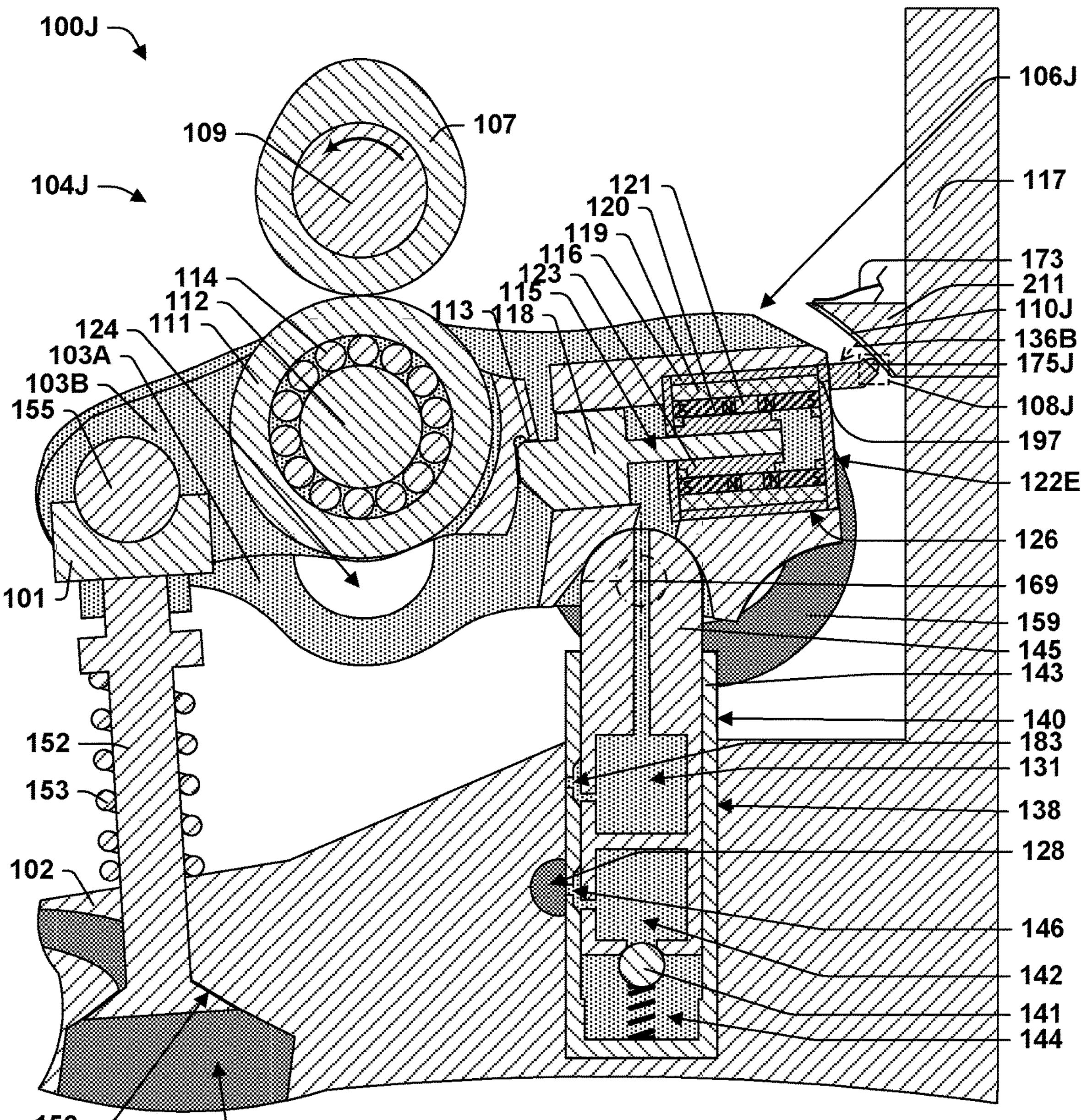
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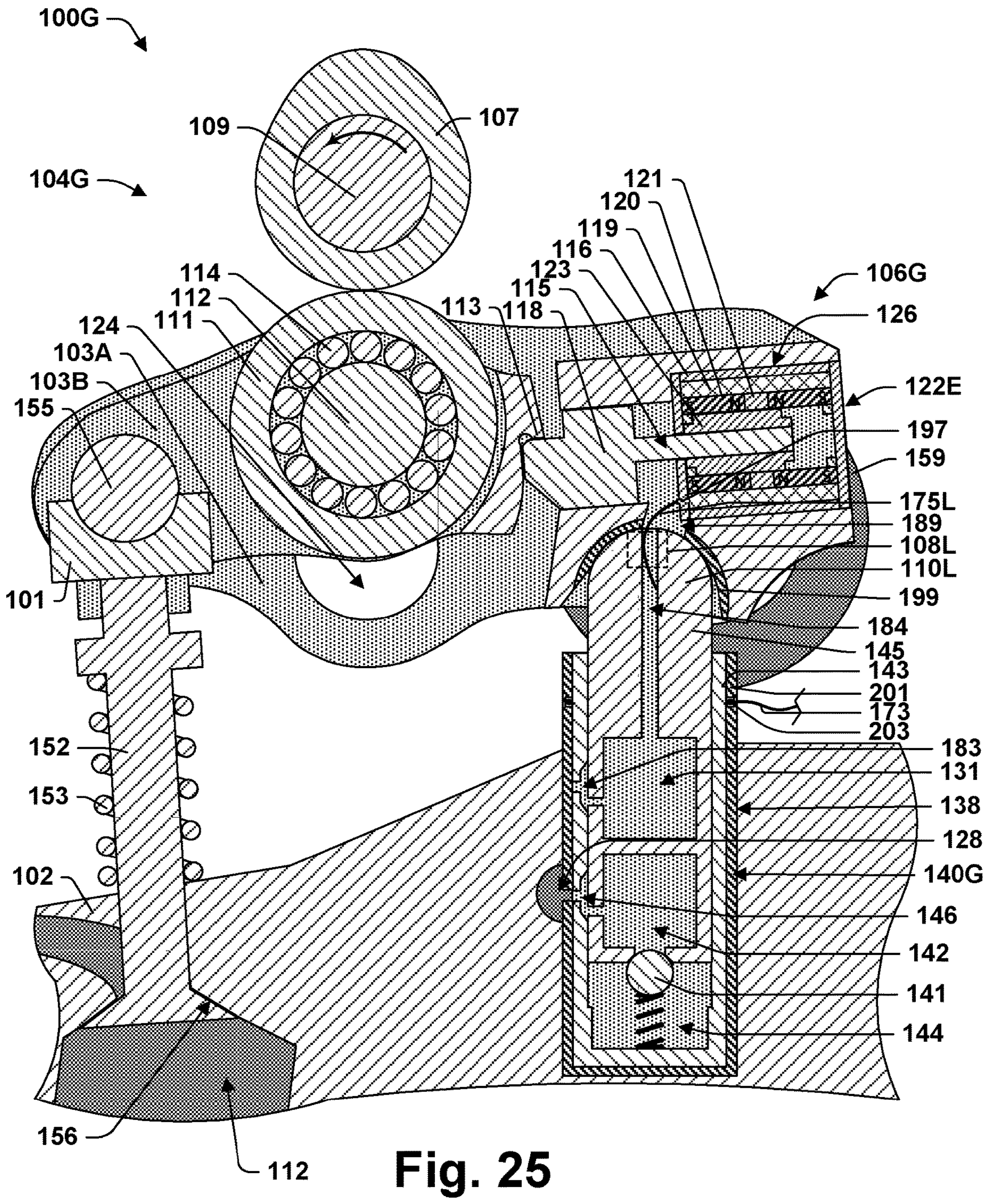
Fig. 24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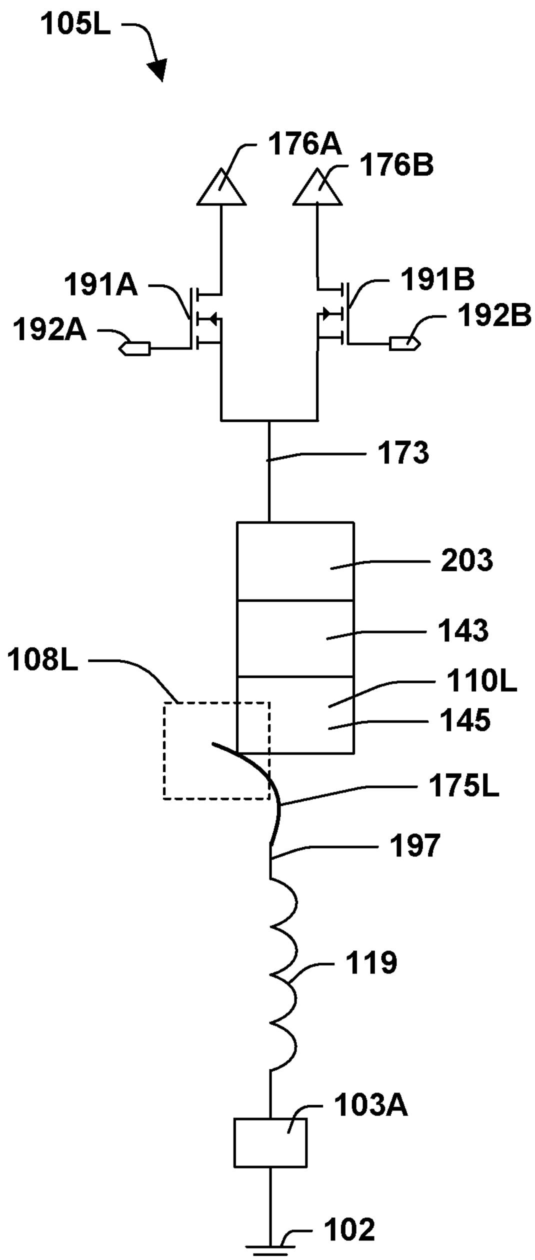
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Fig. 26

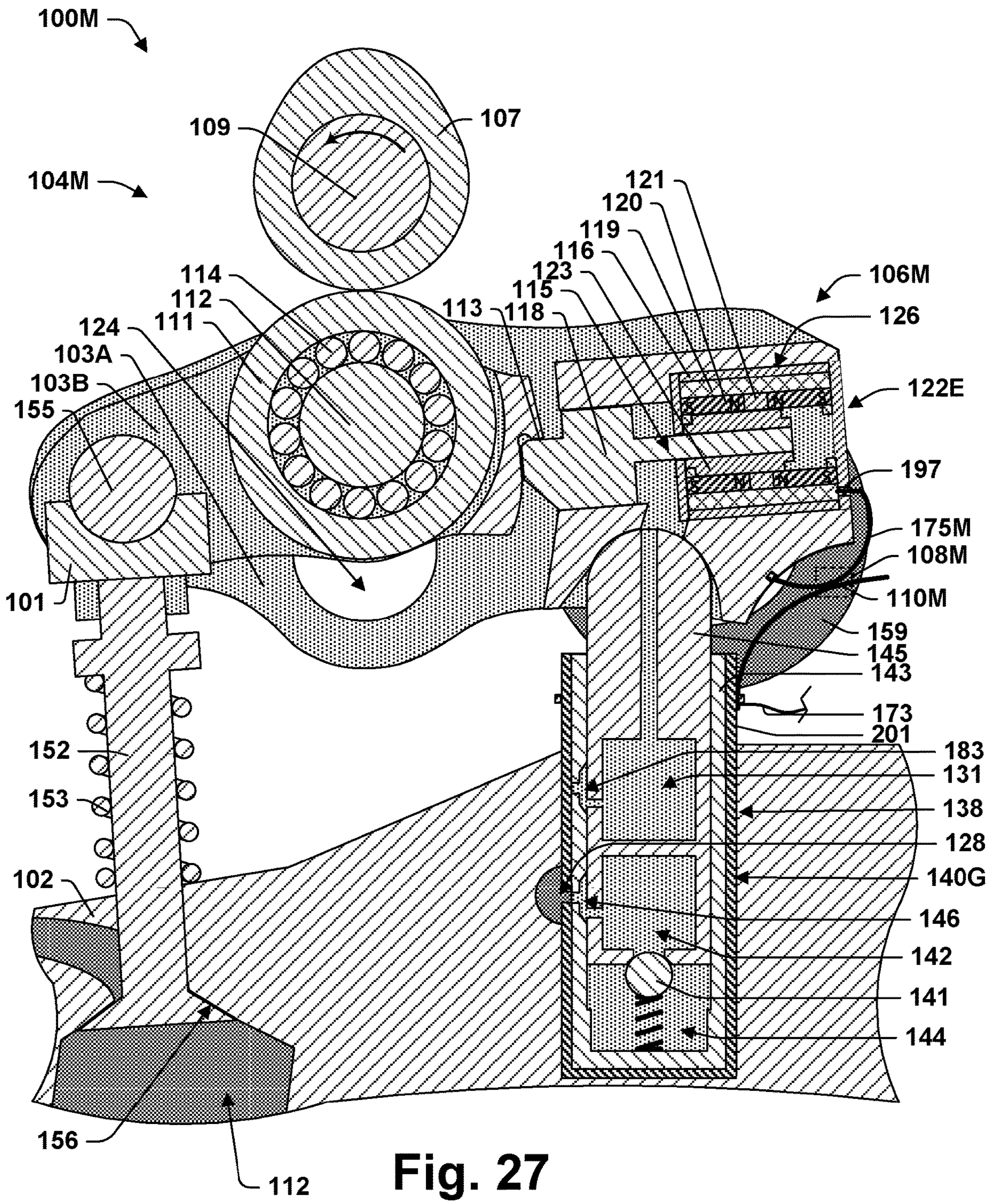
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Fig. 27

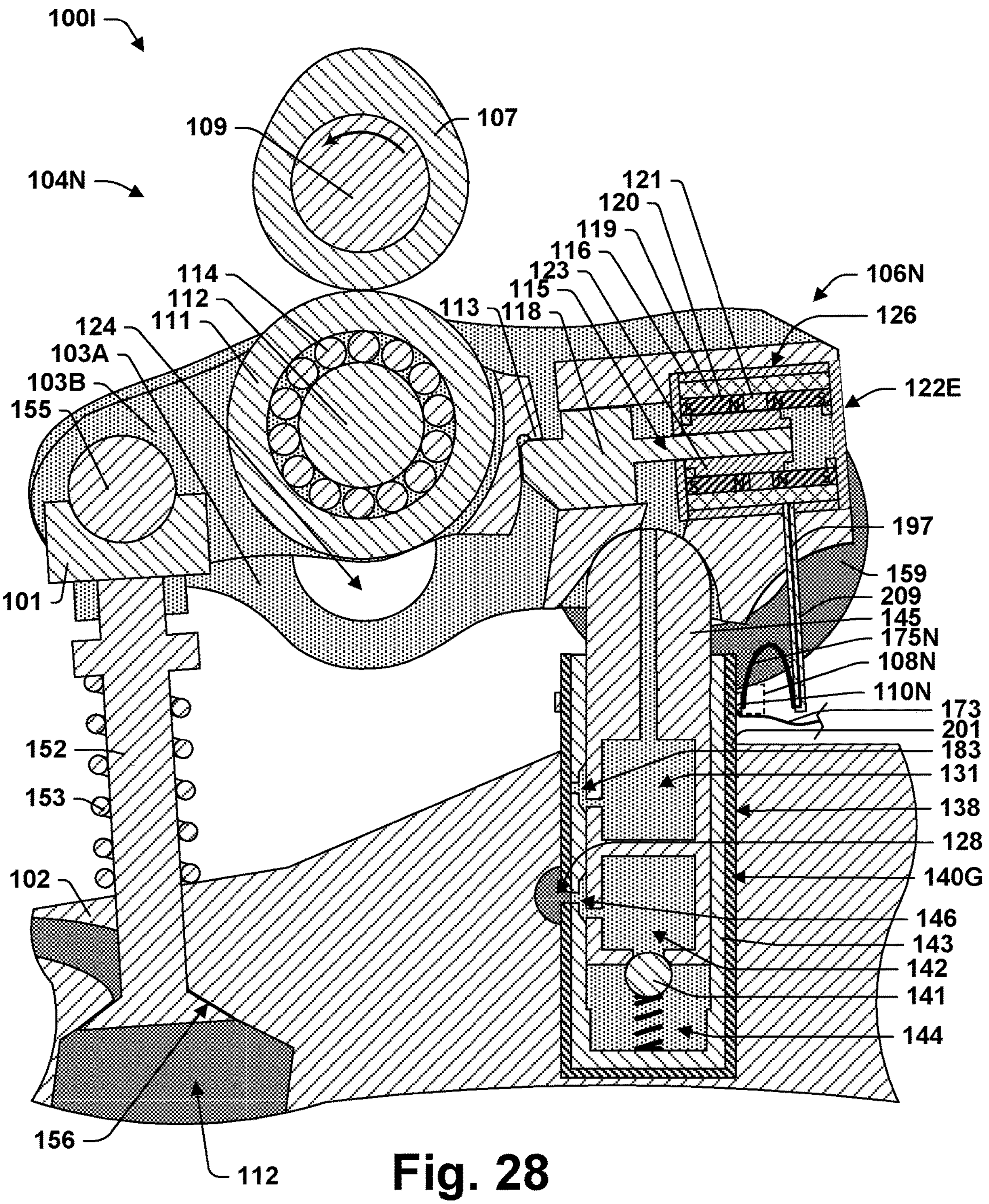
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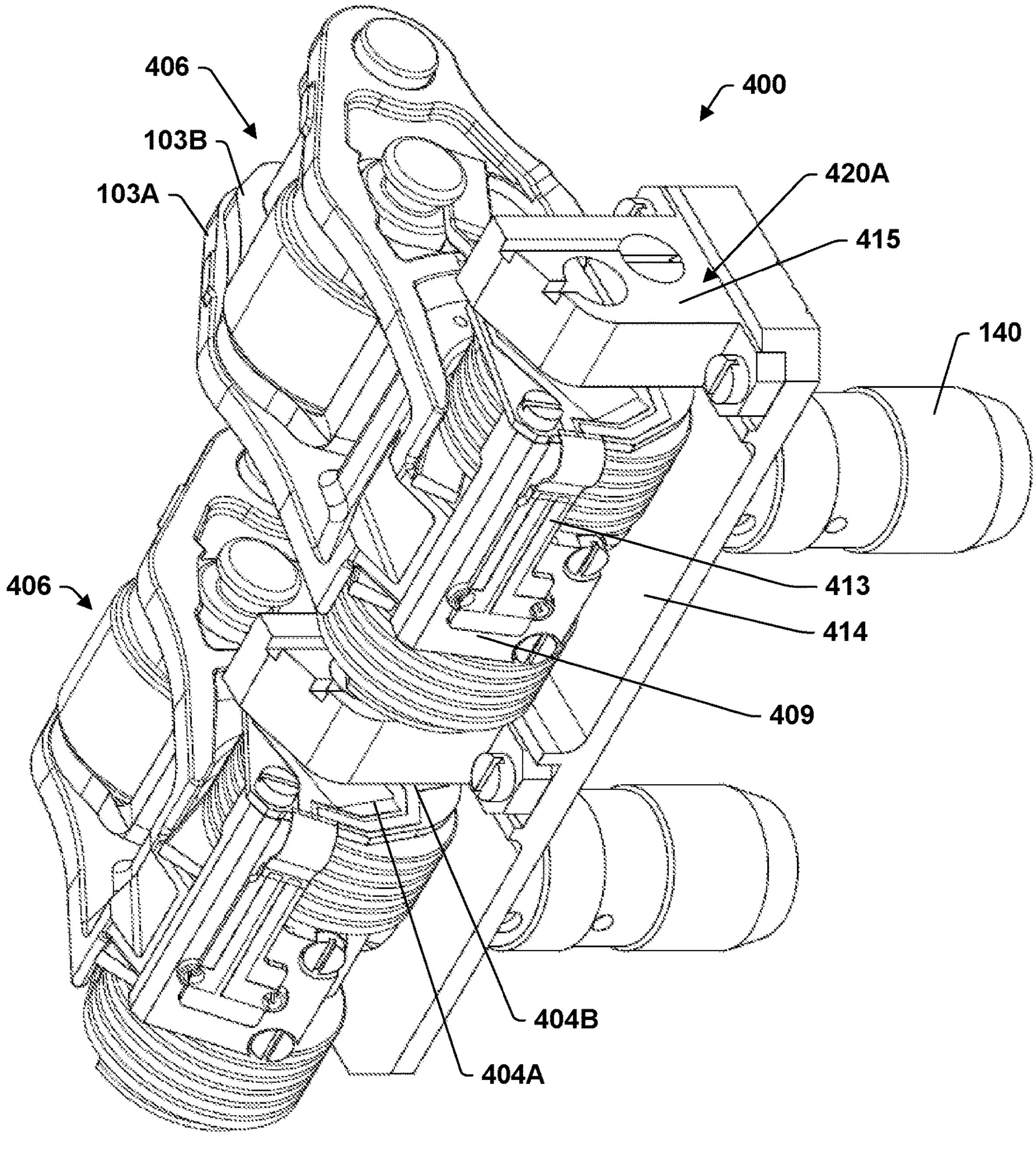
Fig. 28



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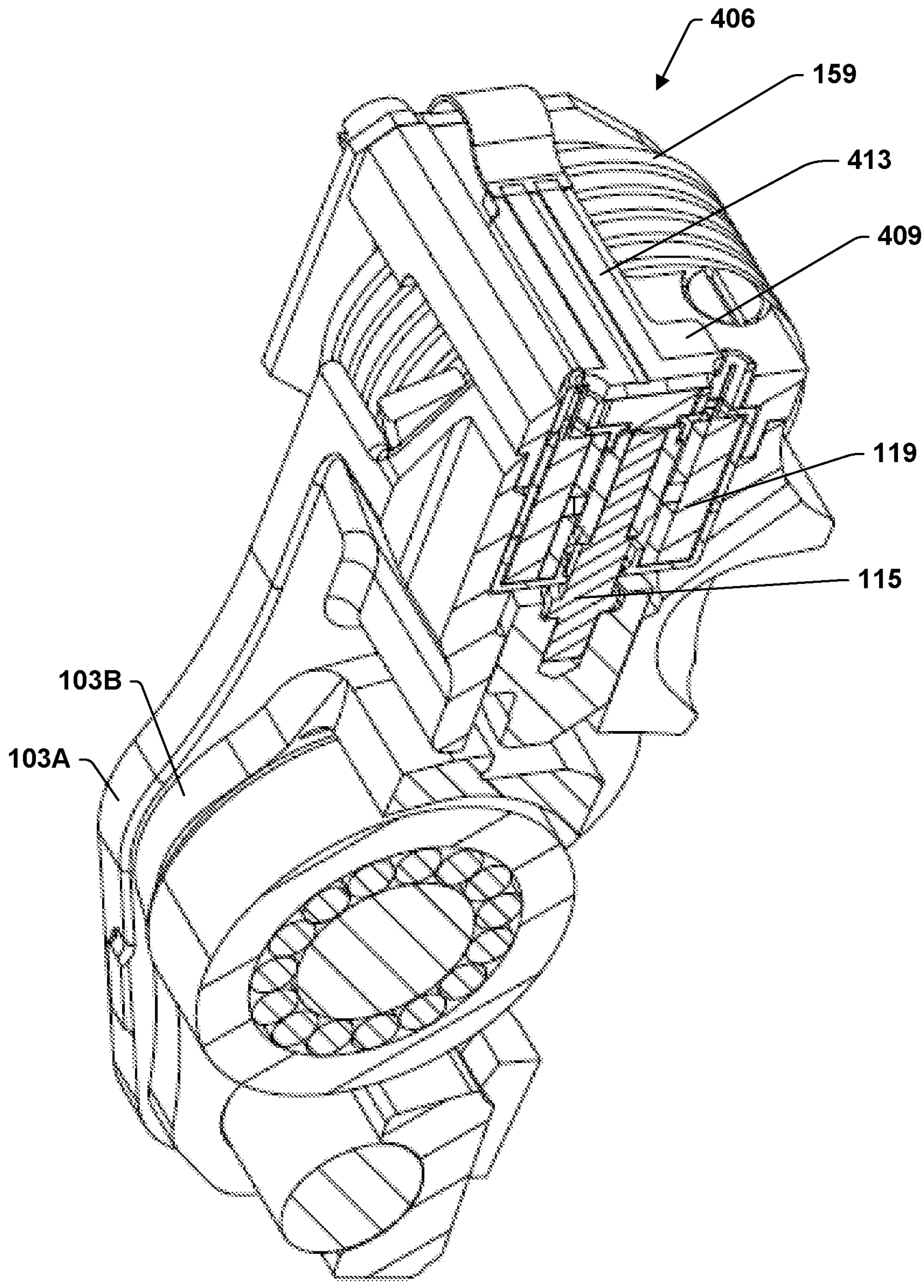

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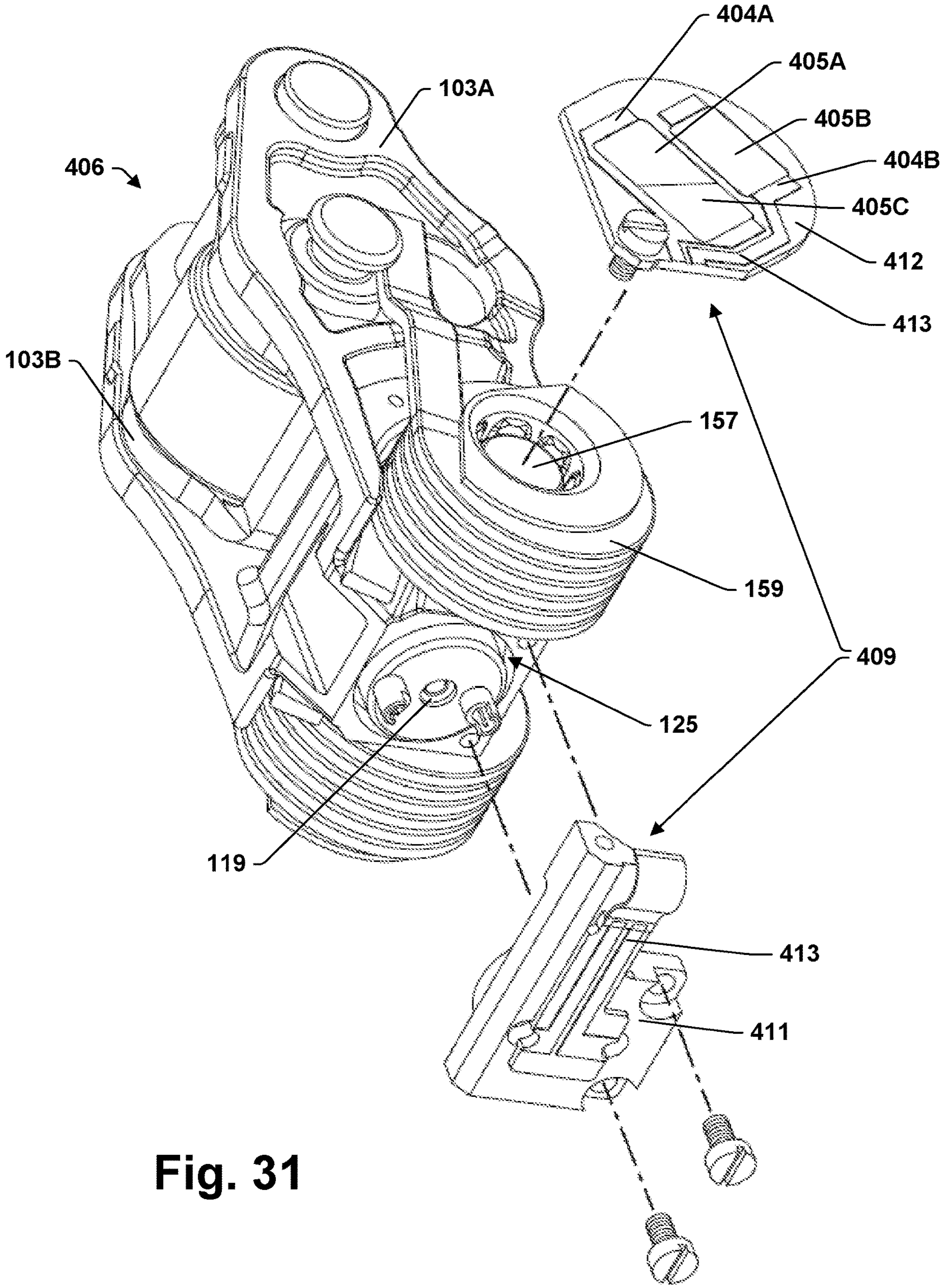
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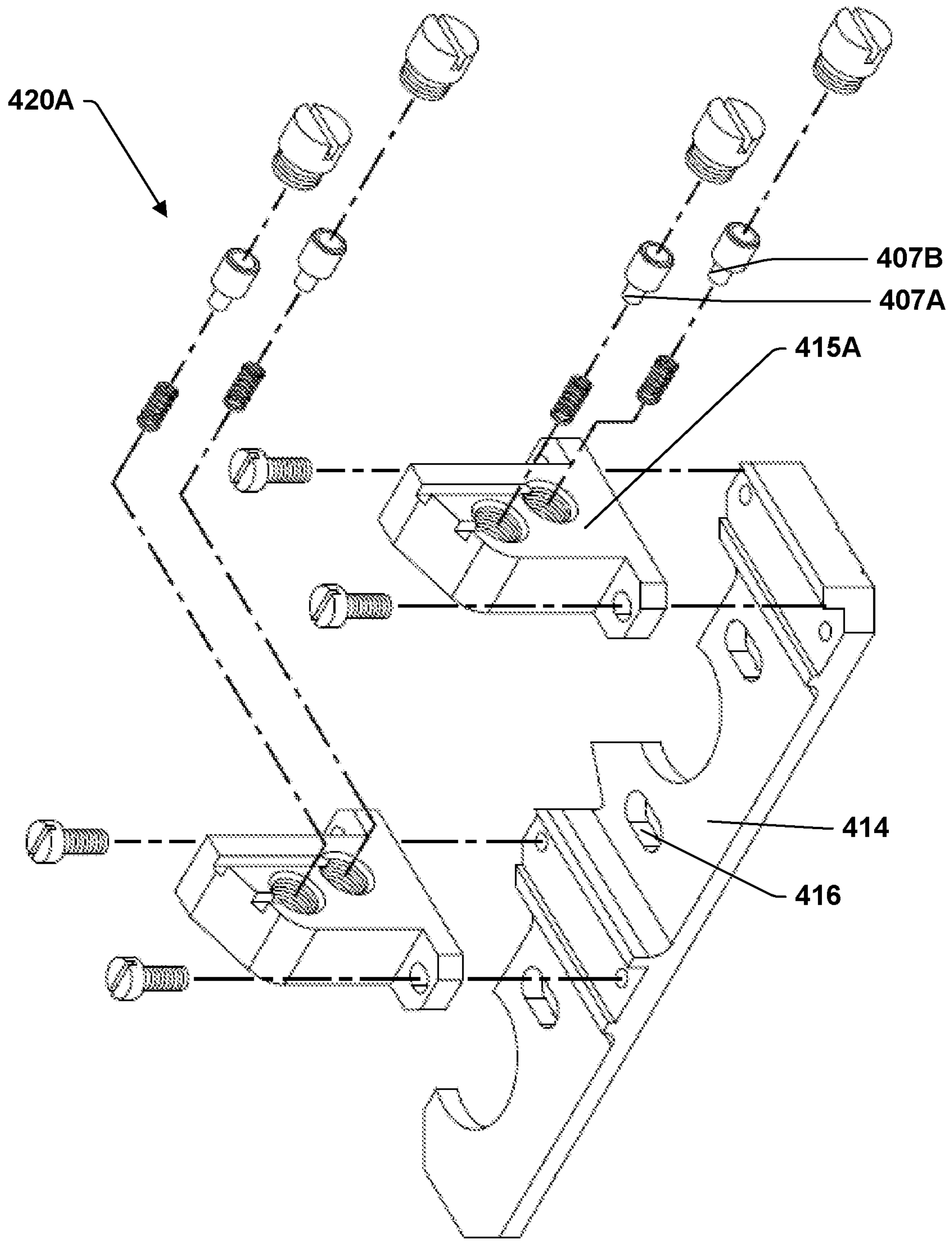
Fig. 31



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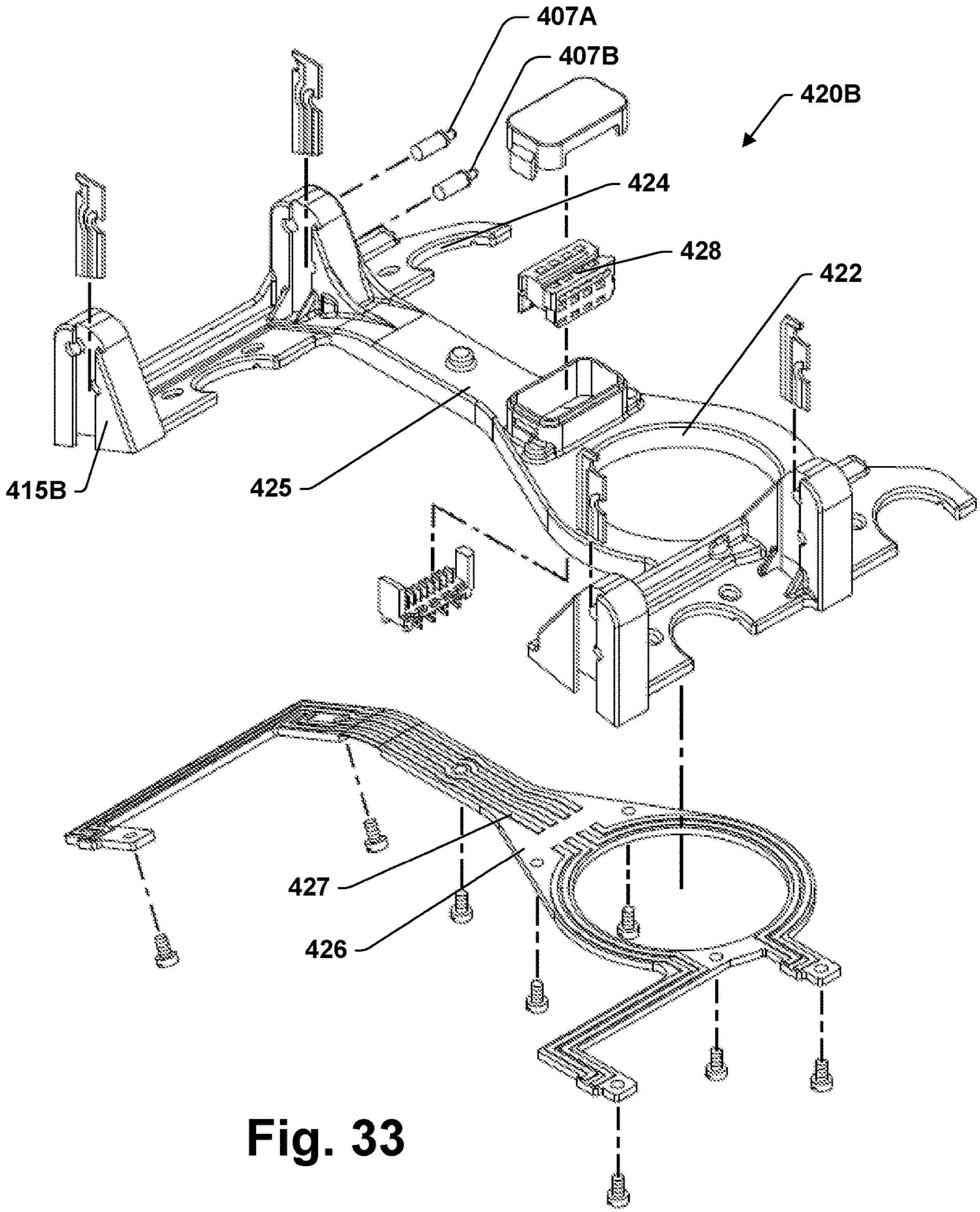

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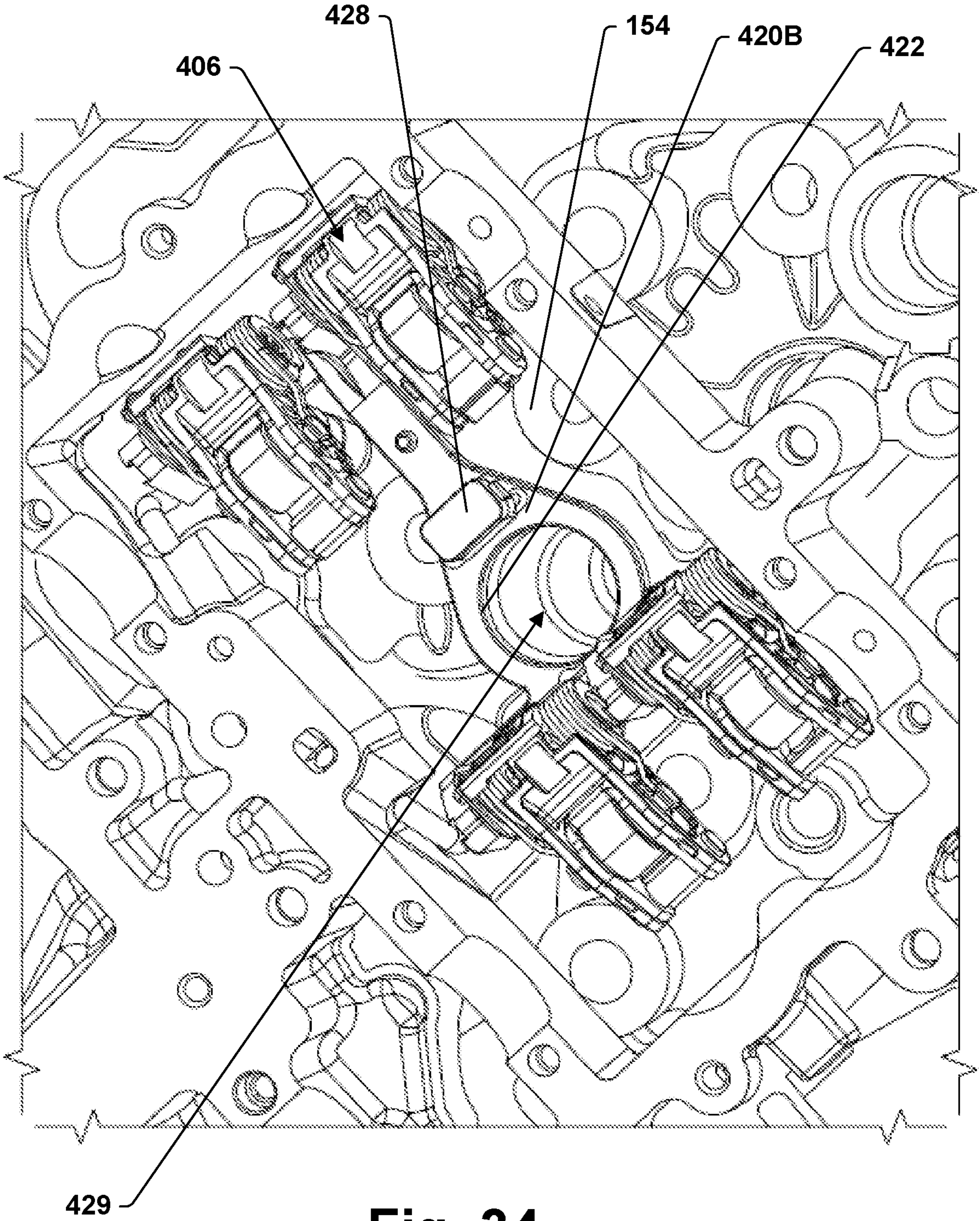

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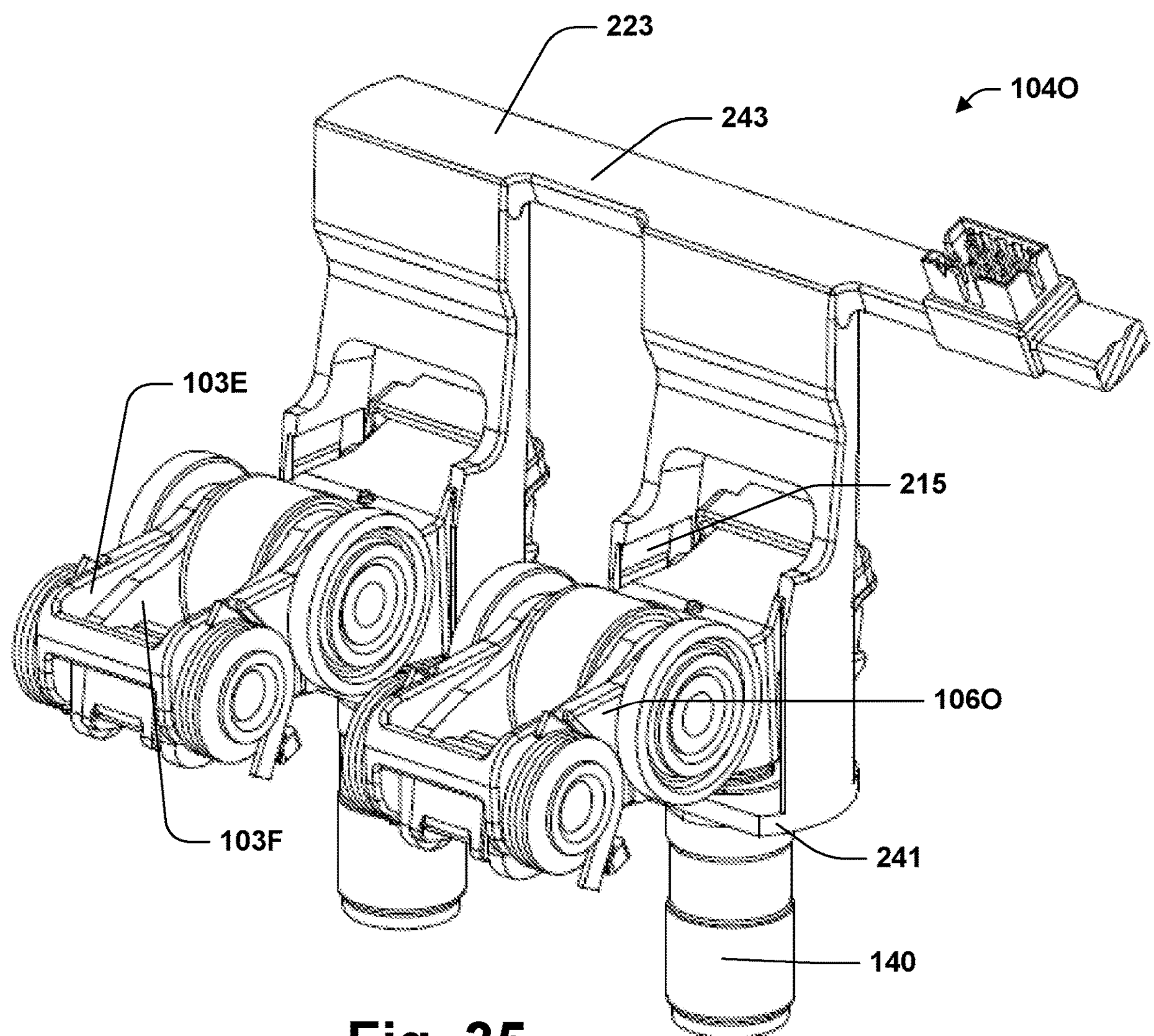

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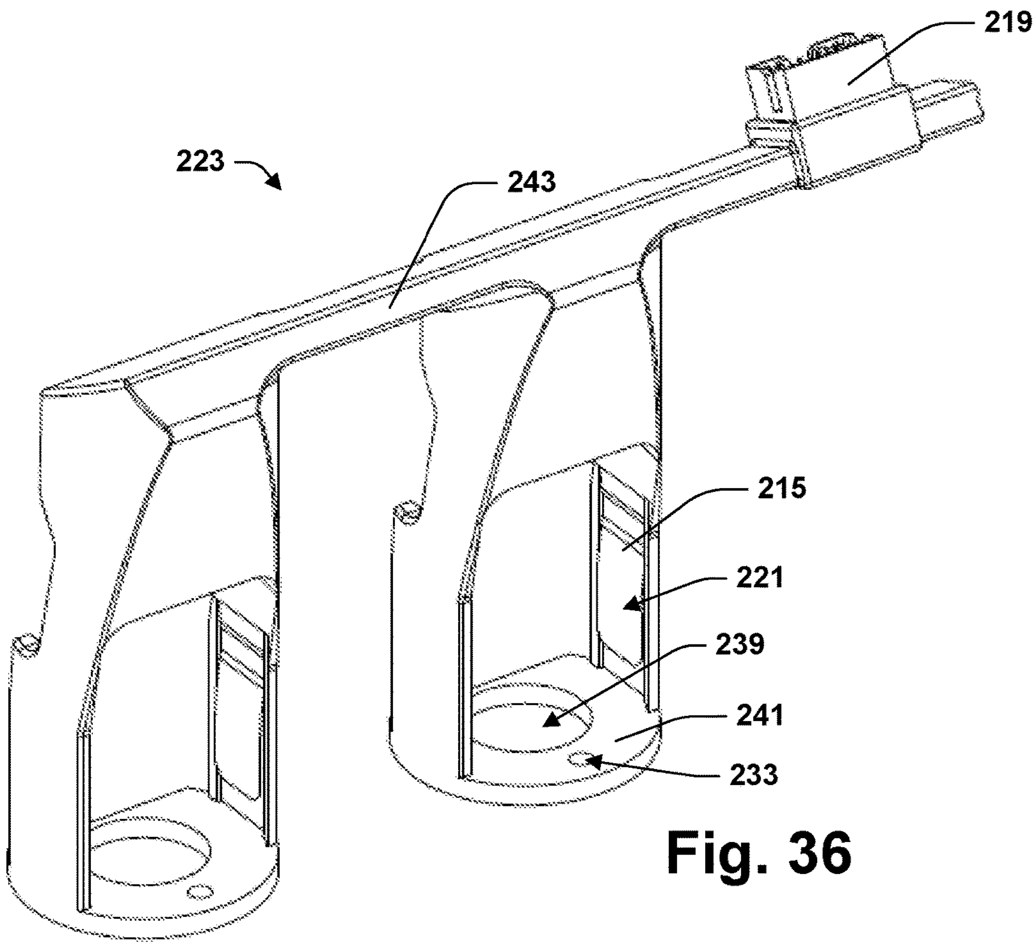

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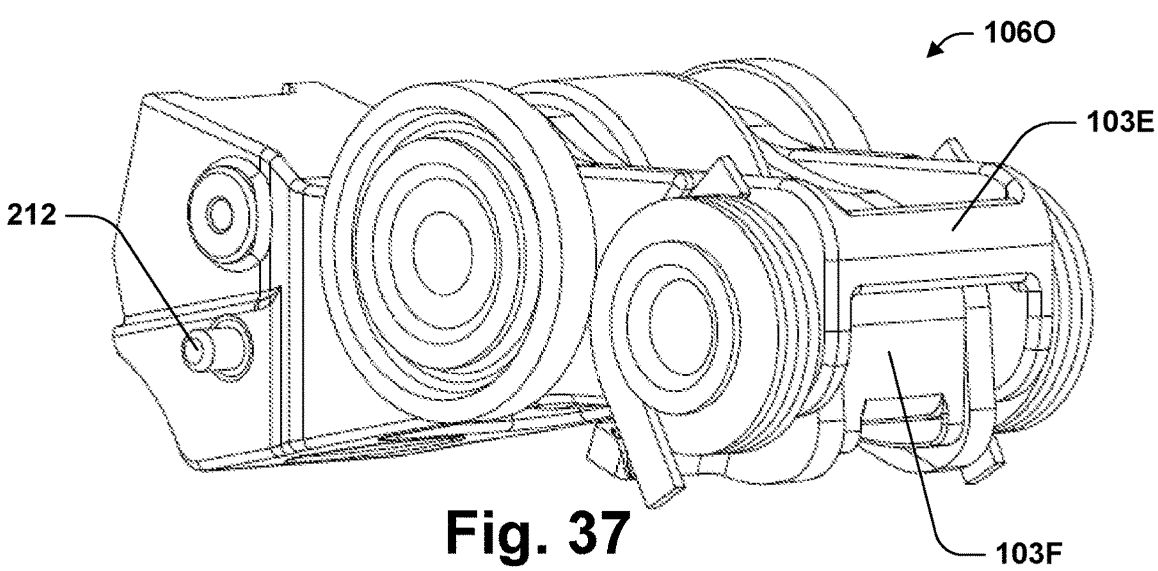

Fig. 37

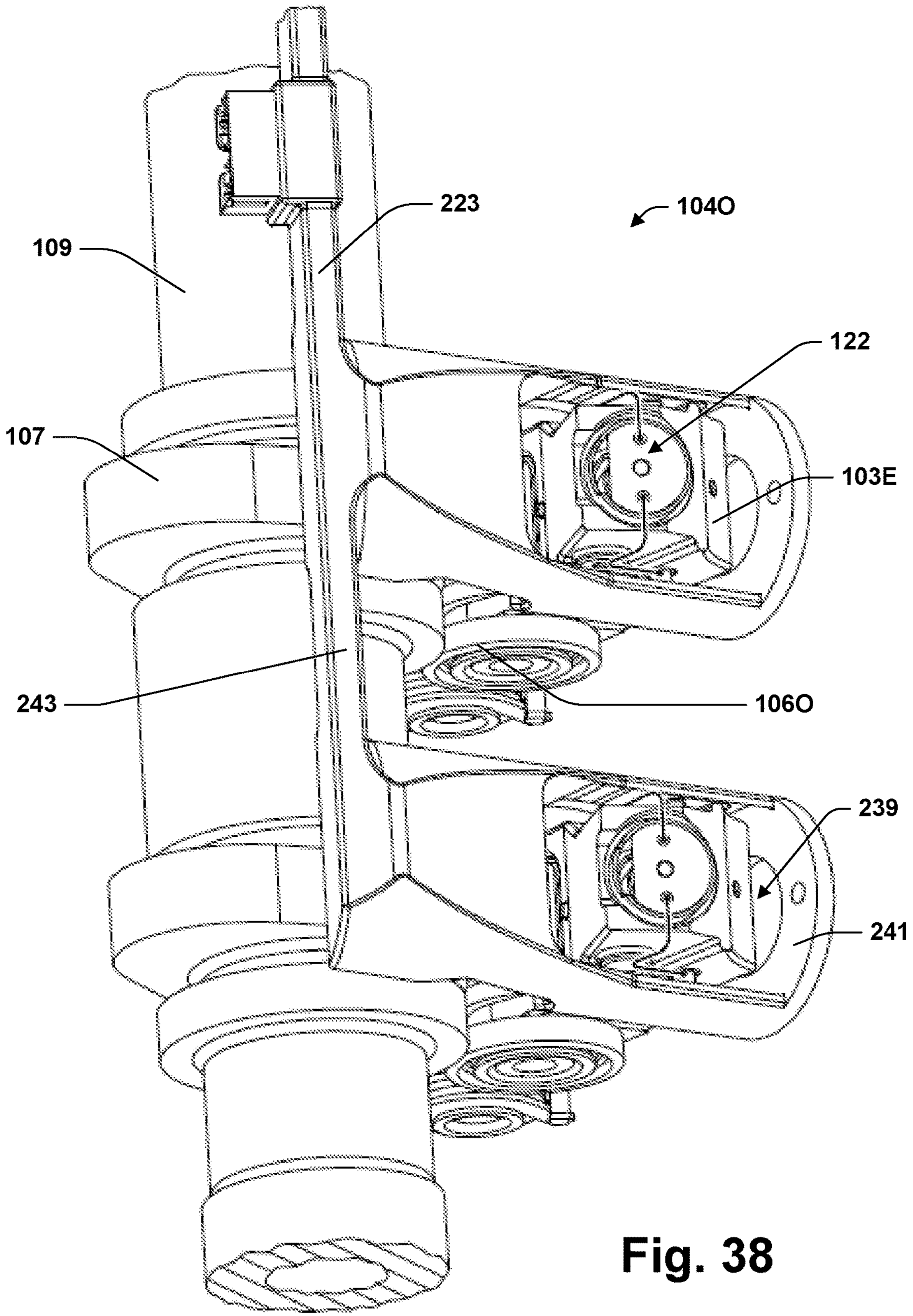

Fig. 38

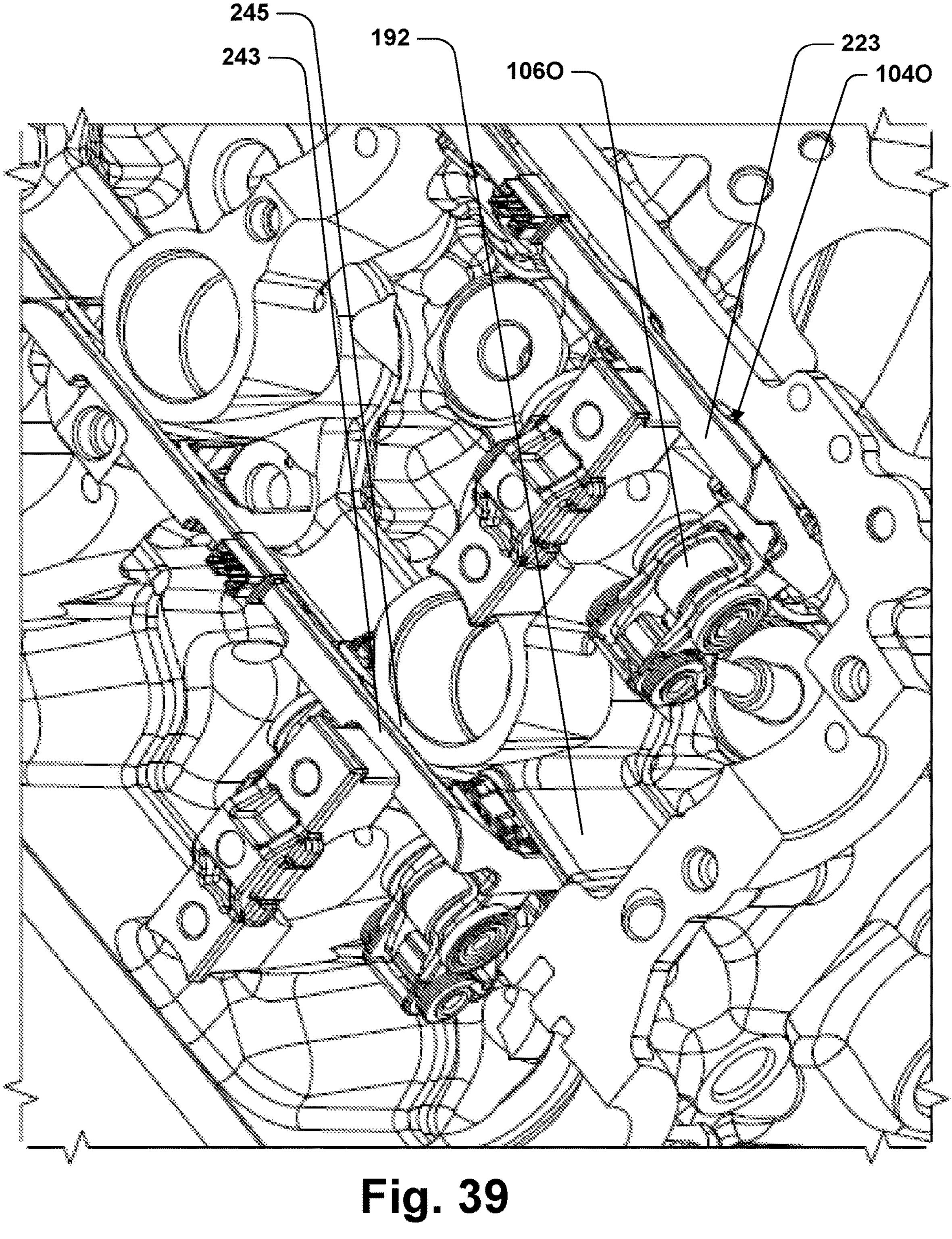

Fig. 39

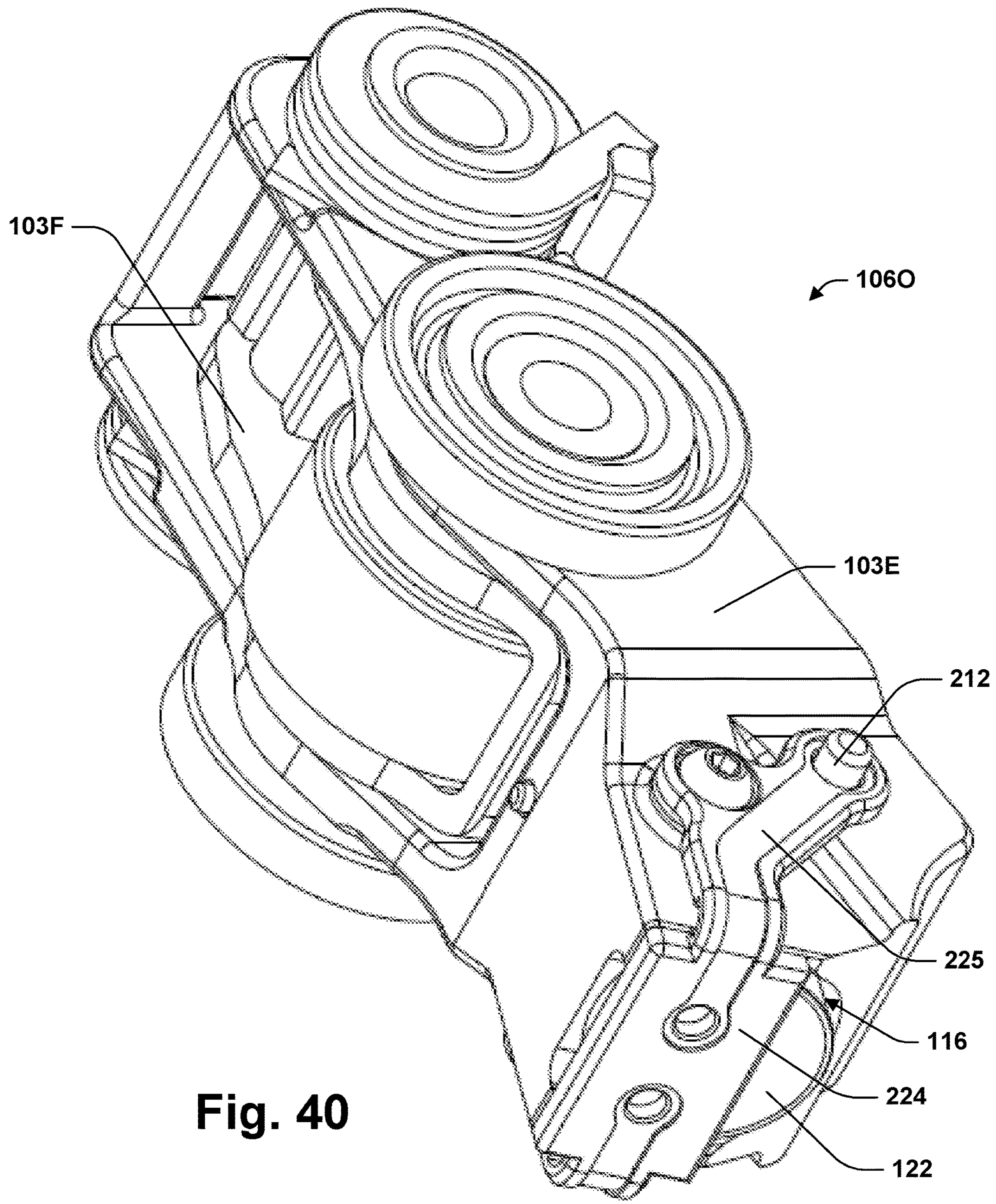

Fig. 40

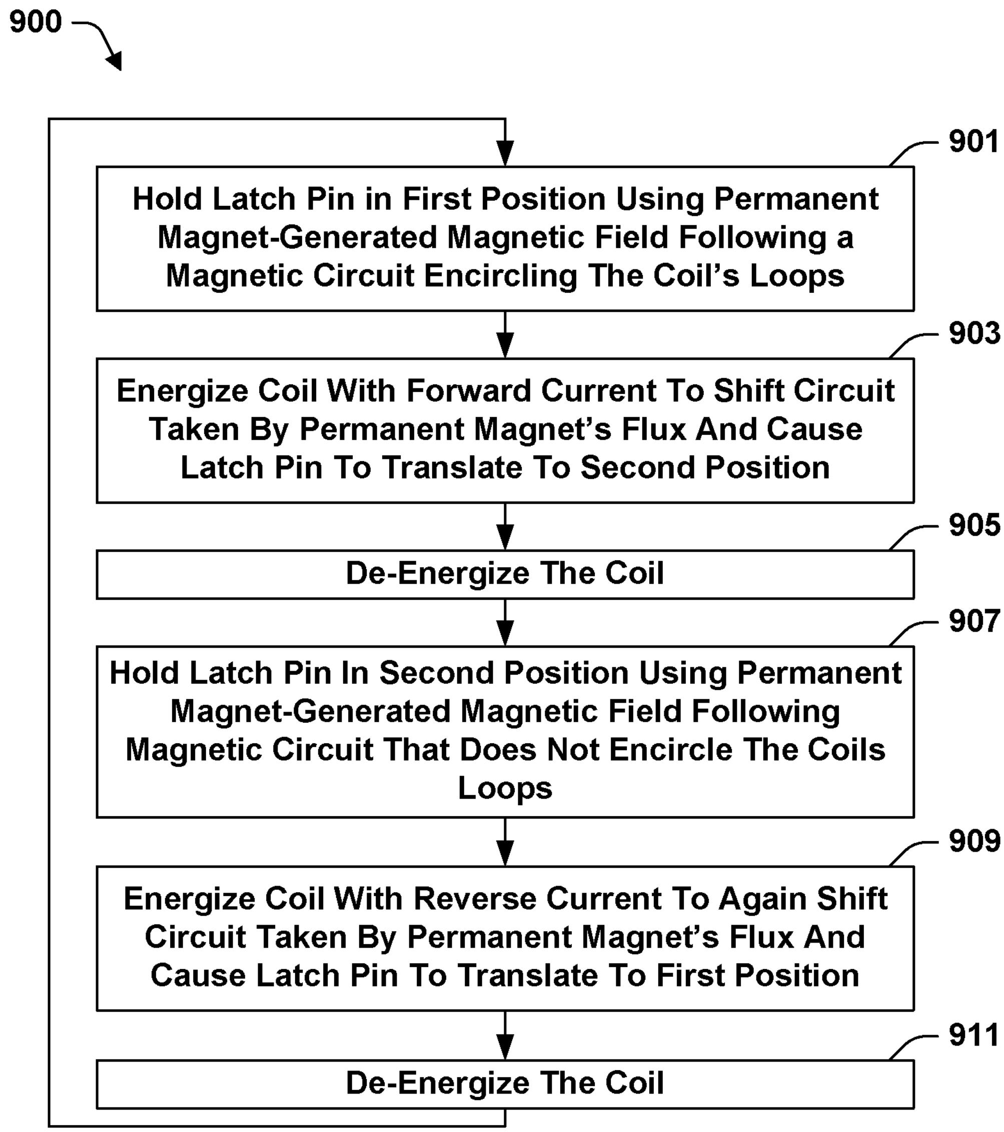
900
901
Hold Latch Pin in First Position Using Permanent Magnet-Generated Magnetic Field Following a Magnetic Circuit Encircling The Coil's Loops
903
Energize Coil With Forward Current To Shift Circuit Taken By Permanent Magnet's Flux And Cause Latch Pin To Translate To Second Position
905
De-Energize The Coil
907
Hold Latch Pin In Second Position Using Permanent Magnet-Generated Magnetic Field Following Magnetic Circuit That Does Not Encircle The Coils Loops
909
Energize Coil With Reverse Current To Again Shift Circuit Taken By Permanent Magnet's Flux And Cause Latch Pin To Translate To First Position
911
De-Energize The Coil

Fig. 41

SLIDING CONTACT FOR ELECTRICALLY ACTUATED ROCKER ARM

PRIORITY

The present application is a divisional of U.S. patent application Ser. No. 16/460,886 filed Jul. 19, 2019, which is a divisional of U.S. patent application Ser. No. 15/863,901 filed Jan. 6, 2018, which claims priority from U.S. Provisional Patent Application No. 62/259,764 filed Nov. 25, 2015, U.S. Provisional Patent Application No. 62/305,612 filed Mar. 9, 2016, PCT Application PCT/US16/63730, filed Nov. 24, 2016, U.S. Provisional Patent Application No. 62/449,174, filed Jan. 23, 2017, U.S. patent application Ser. No. 15/503,458, filed Feb. 13, 2017, U.S. Provisional Patent Application No. 62/488,747, filed Apr. 22, 2017, and U.S. Provisional Patent Application No. 62/503,303, filed May 8, 2017, which applications are incorporated by reference in their entireties.

FIELD

The present teachings relate to valvetrains, particularly valvetrains providing variable valve lift (VVL) or cylinder deactivation (CDA).

BACKGROUND

Hydraulically actuated latches are used on some rocker arm assemblies to implement variable valve lift (VVL) or cylinder deactivation (CDA). For example, some switching roller finger followers (SRFF) use hydraulically actuated latches. In these systems, pressurized oil from an oil pump may be used for latch actuation. The flow of pressurized oil may be regulated by an oil control valve (OCV) under the supervision of an engine control unit (ECU). A separate feed from the same source provides oil for hydraulic lash adjustment. In these systems, each rocker arm assembly has two hydraulic feeds, which entails a degree of complexity and equipment cost.

The oil demands of these hydraulic feeds may approach the limits of existing supply systems. The complexity and demands for oil in some valvetrain systems can be reduced by replacing hydraulically latched rocker arm assemblies with electrically latched rocker arm assemblies. Electrically latched rocker arm assemblies require power.

SUMMARY

The present teachings relate to powering or communicating with an electronic device such as a solenoid that is mounted to a mobile portion of a rocker arm assembly such as a rocker arm. If the electronic device is powered with conventional wiring, it is a possible for a wire to be caught, clipped, or fatigued and consequently short out. The present teachings provide a valvetrain suitable for an internal combustion engine that includes a combustion chamber, a moveable valve having a seat formed within the combustion chamber, and a camshaft. The valvetrain includes a rocker arm assembly. The rocker arm assembly includes a rocker arm, a cam follower configured to engage a camshaft-mounted cam as the camshaft rotates, and an electrical device mounted to the rocker arm.

According to some aspects of the present teachings, an electrical circuit that of which the electrical device is a part includes a connection formed by abutment between the surfaces of two distinct parts. The rocker arm assembly is

operative to move one of the two abutting surfaces relative to the other in response to actuation of the cam follower. The abutting surfaces of the two distinct parts may be electrically isolated from ground, whereby the connection may be used for powering or communicating with the electrical device. The ground may correspond to a cylinder head of an engine in which the valvetrain is installed. Forming the connection through abutting surfaces that are free to undergo relative motion may reduce or eliminate the need to run wires between parts that undergo relative motion.

According to some aspects of the present teachings, one of the two distinct parts forming the electrical connection is mounted to the rocker arm assembly and the other is not. In some of these teachings the part mounted to the rocker arm assembly is mounted to the rocker arm on which the electrical device is mounted. In some of these teachings, the part not mounted to the rocker arm assembly is mounted to a frame that has a base that fits against a pivot that provides a fulcrum for the rocker arm assembly. In some of these teachings, the frame fits around a pivot that provides a fulcrum for the rocker arm assembly. In some of these teachings, the frame also rests against a cylinder head in which the combustion chamber is formed. In some of these teachings, the frame rests against the cylinder head at a point on the cylinder head that is higher above the combustion chamber than the rocker arm assembly and at a point on the cylinder head that is less high above the combustion chamber than the rocker arm assembly. In some of these teachings, the part not mounted to the rocker arm assembly is mounted to a frame that has a base that abuts two or more pivots that provide fulcrums for rocker arm assemblies of the valvetrain.

In some of these teachings, one of the two distinct parts that forms the electrical connection is mounted to the rocker arm and the other is mounted to a pivot providing a fulcrum for that rocker arm. In some of these teachings, the pivot is a lash adjuster, such as a hydraulic lash adjuster. Mounting the one part to the rocker arm and the other to the pivot or in abutment with the pivot may facilitate positioning the two parts forming the electrical connection relative to one another. The part mounted to the pivot may be connected to an engine electrical system through wires that undergo relatively little motion.

According to some aspects of the present teachings, a load-bearing member of the valvetrain forms part of the electrical circuit. In some of these teachings, the portion of the load-bearing structure that forms a portion of the electrical circuit is isolated from ground. In some of these teachings, the load-bearing structure is a pivot. In some of these teachings, the load-bearing structure is a cam. In some of these teachings, the load-bearing structure is a cam follower. In some of these teachings, the electrical connection is formed at a load-bearing interface between two structures of the valvetrain.

In some of these teachings, the electrical device is powered through the electrical circuit. In some of these teachings, the electrical device is an electromagnetic latch assembly. In some of these teachings, the electrical device communicates with a processor through the electrical circuit. In some of these teachings, the electrical device is a sensor.

According to some aspects of the present teachings, one of the two distinct parts forming the electrical connection is mounted to the rocker arm bearing the electrical device and the rocker arm is operative to pivot in response to actuation of the cam follower by a camshaft-mounted cam. The pivoting is operative to cause one of the two distinct parts to

move relative to the other. In some of these teachings, the electrical connection is made proximate the axis of pivoting. Forming the connection near the axis of pivoting keeps motion between the two distinct parts comparatively small. In some of these teachings, one of the parts forming the electrical connection is mounted over a spring post on the rocker arm. The spring post may be located proximate the axis of pivoting.

In some of these teachings, one of the surfaces forming the electrical connection is oriented parallel to a plane to which the axis of pivoting is perpendicular. In some of these teachings, at least one of the two part surfaces forming the electrical connection is relatively flat and has a surface normal vector that is substantially parallel to the axis of pivoting. In some of these teachings the surface normal vector is nearly perpendicular to a direction in which a lash adjuster extends to adjust lash.

In some others of these teachings, one of the two part surfaces has a surface normal vector that points approximately toward or directly away from the axis about which the pivoting occurs. In some of these other teachings, one of the two part surfaces has a radius of curvature that is approximately equal to the surface's distance from the axis about which the pivoting occurs. The foregoing structures may facilitate maintaining contact between the two distinct parts forming the electrical connection even as the parts undergo relative motion due to pivoting of the rocker arm.

According to some aspects of the present teachings, one of the two distinct parts is a contact held to a side of the rocker arm by a contact frame that is supported within an opening at the back of the rocker arm. In some of these teaching, the contact frame is secured to the sides of the rocker arm as well.

In some aspects of these teachings, one of the two part surfaces forming the electrical connection is a projecting conductive member. The projecting conductive member may be rigid. For example, the projecting conductive member may be a metal pin projecting outward from a rocker arm. In some of these teachings, the projecting conductive member projects outward from a rocker arm parallel or nearly parallel to an axis on which the rocker arm pivots. In some of these teachings, the projecting conductive member is mounted to the rocker arm and is located proximate an axis on which the rocker arm pivots.

The surfaces forming the electrical connection may be exposed to the environment of the rocker arm assembly and may become coated with a thin layer of engine oil. In some of these teachings, the rocker arm assembly is operative to cause the surface of one of the two distinct parts to slide over the other. In some of these teachings, one of the parts is a brush. Brushes may have the effect of pushing oil from between the abutting surfaces of the two distinct parts. In some of these teachings, one of the two distinct parts is configured to roll over the other. Rolling contact may have the advantage of reduced wear.

According to some aspects of the present teachings, a lash adjuster provides a fulcrum on which the rocker arm assembly pivots. In some of these teachings, one of the surfaces forming the electrical connection runs parallel to a direction in which the lash adjuster extends to adjust lash. In some of these teachings, the surfaces of the two distinct parts forming the electrical connection are configured to slide one past the other while remaining in contact as the lash adjuster extends and retracts to adjust lash. In some of these teachings, the lash adjuster is a hydraulic lash adjuster and the surfaces of the two distinct parts forming the electrical connection are configured to maintain the electrical connection as the lash adjuster extends and retracts between pumped up and depressurized states. These structures facilitate maintaining contact between the two distinct parts even as one of the parts is moved relative to the other as a result of lash adjustment.

According to some aspects of the present teachings, the valvetrain includes a spring biasing one of the two distinct parts whose abutting surfaces form the electrical connection against the other. In some of these teachings the spring itself forms part of the electrical circuit. The spring may facilitate good contact and compensate for wear. In some of these teachings, one of the parts is a pogo pin connector. In some of these teachings, the spring is a leaf spring. In some of these teachings, an end of the leaf spring is held stationary relative to the combustion chamber.

According to some aspects of the present teachings, the electrical connection is made within an interface between load-bearing members of the valvetrain. In some of these teachings, the electrical circuit is completed by a mechanical interface between two load bearing structures of the valvetrain. In some of these teachings, one of the two parts forming the electrical connection includes an insulating structure surrounding the surface through which the electrical connection is made. In some of these teachings the connection is made within an area of contact between a lash adjuster and a rocker arm. Forming the connection within a load-bearing interface keeps the connection within a volume already occupied by the rocker arm assembly.

According to some aspects of the present teachings, one of the two distinct parts forming the electrical connection is a conductor integrated into the structure of a load-bearing member of the valvetrain. In some of these teachings, the conductor is a conductive trace formed on a surface of the load-bearing member. In some of these teachings, the load-bearing member is a valve stem. In some of these teachings, the load-bearing member is a pivot.

In some of these teachings, the electrical device is an electromagnetic latch assembly having a latch pin translatable between a first position and a second position. One of the first and second latch pin positions provides a configuration in which the rocker arm assembly is operative to actuate a moveable valve in response to actuation of the cam follower by a camshaft-mounted cam to produce a first valve lift profile. The other of the first and second latch pin positions provides a configuration in which the rocker arm assembly is operative to actuate the moveable valve in response to actuation of the cam follower by the camshaft-mounted cam to produce a second valve lift profile, which is distinct from the first valve lift profile, or the moveable valve is deactivated. This structure may provide cylinder deactivation (CDA) or variable valve lift (VVL).

In some of these teachings, the electromagnetic latch assembly include a coil operable to actuate the latch pin between the first and second positions. In some of these teachings the electromagnetic latch assembly provides the latch pin with positional stability independently from the coil when the latch pin is in the first position and when the latch pin is in the second position. In some of these teachings, the electromagnetic latch assembly is operable with a DC current in a first direction to actuate the latch pin from the first position to the second positions and with a DC current in a second direction, which is a reverse of the first, to actuate the latch pin from the second position to the first position. Having the electromagnetic latch assembly make the latch pin stable without power in both the first and the second positions allows the electrical connection to be broken without the latch pin position changing.

According to some other aspects of the present teachings, the coil or a permanent magnet forming part of the electromagnetic latch assembly is rigidly mounted to the rocker arm and the electromagnetic latch assembly provides the latch pin with positional stability independently from the coil when the latch pin is in the first position and when the latch pin is in the second position. This dual positional stability enables the latch to retain both latched and unlatched states without reliance on the coil. The coil then does not need to be powered and need not be operative on the latch pin except for latch pin actuation, which may be limited to times at which the cam is on base circle. This can facilitate the implementation of an electromagnetic latch assembly a portion which is mounted on a rocker arm that moves rapidly at times over the course of its operating cycle. Installing a significant portion of an electromagnetic latch assembly, including at least the coil or a permanent magnet, on the rocker arm can provide a more compact design as compared to one in which an electromagnetic latch assembly is mounted off the rocker arm.

According to some aspects of the present teachings, a permanent magnet contributes to the positional stability of the latch pin both when the latch pin is in the first position and when the latch pin is in the second position. According to some further aspects of these teachings, the electromagnetic latch assembly is structured to operate through a magnetic circuit shifting mechanism. In some of these teachings, absent any magnetic fields generated by the electromagnet or other external sources, when the latch pin is in the first position, an operative portion of the magnetic flux from the permanent magnet follows a first magnetic circuit and when the latch pin is in the second position, an operative portion of the magnetic flux from the permanent magnet follows a second magnetic circuit distinct from the first magnetic circuit. The coil may be operative to redirect the permanent magnet's flux away or toward one or the other of these magnetic circuits and thereby cause the latch pin to actuate. In some of these teachings redirecting the magnetic flux includes reversing the magnetic polarity in a low coercivity ferromagnetic element forming part of both the first and second magnetic circuits. An electromagnetic latch assembly structured to be operable through a magnetic circuit shifting mechanism may be smaller than one that is not so structured. In some of these teachings, the permanent magnet is fixedly mounted to the rocker arm. Fixing the permanent magnet to the rocker arm means not fixing the permanent magnet to the latch pin. Taking the weight of the permanent magnet off the latch pin may increase actuation speed and allow the use of a smaller coil.

In some of these teaching, the coil encircles a volume within which a portion of the latch pin comprising low coercivity ferromagnetic material translates and the electromagnetic latch assembly comprises one or more sections of low coercivity ferromagnetic material outside the volume encircled by the coil. Both the first and the second magnetic circuits pass through the latch pin portion formed of low coercivity ferromagnetic material. In some of these teachings, the first magnetic circuit passes around the outside of the coil via the one or more sections of low coercivity ferromagnetic material while the second magnetic circuit does not pass around the outside of the coil. This characteristic of the second magnetic circuit reduces magnetic flux leakage and increases the holding force per unit mass provided by the permanent magnet when the latch pin is in the second position.

In some of these teachings, the electromagnetic latch assembly includes a second permanent magnet distal from the first and fulfilling a complimentary role. The electromagnetic latch assembly may provide two distinct magnetic circuits for the second permanent magnet, one or the other of which is the path taken by an operative portion of the magnet flux from the second permanent magnet depending on the whether the latch pin is in the first position or the second position. The path taken when the latch pin is in the second position may pass around the outside of the coil via the one or more sections of low coercivity ferromagnetic material. The path taken when the latch pin is in the first position may be a shorter path that does not pass around the outside of the coil. One or the other of the permanent magnets may then provide a high holding force depending on whether the latch pin is in the first or second positions. In some of these teachings, both permanent magnets contribute to the positional stability of the latch pin in both the first and the second latch pin positions. In some of these teachings, the two magnets are arranged with confronting polarities. In some of these teachings, the two magnets are located at distal ends of the volume encircled by the coil. In some of these teachings, the permanent magnets are annular in shape and polarized along the directions of the axes. These structures may be conducive to providing a compact and efficient design.

In some of these teachings, the electromagnetic latch assembly includes two permanent magnets arranged with confronting polarities and with a pole piece of magnetically susceptible material between them. In some of these teachings, the magnetically susceptible material is a low coercivity ferromagnetic material. The magnets and the pole piece are fixed to the rocker arm and arranged about an opening through which the latch pin translates. In some of these teaching, the pole piece bounds the opening. The permanent magnets may also bound the opening. In some of these teachings, the pole piece bounds the opening more narrowly than the magnets, whereby the latch pin contacts the pole piece but does not contact either of the magnets. In this configuration, the pole piece helps secure the latch pin against rocking while the permanent magnets are relieved of stress.

A shell surrounding the coil may have an opening through which the latch pin extends. In accordance with some aspects of the present teachings, the latch pin has a non-circular profile where it passes through that opening. The shape of the opening cooperates with the latch pin profile to restrict rotation of the latch pin. This structure provides an anti-rotation function and facilitates smooth operation of the latch pin, particularly when the latch pin is supported within the coil.

In some of the present teaching, the electromagnetic latch assembly includes at least one permanent magnet and the internal combustion engine has circuitry operable to energize the coil with a current in either a first direction or a second direction, which is the reverse of the first direction. A latch having dual positional stability may require the coil current to be in one direction for latching and the opposite direction for unlatching. The coil powered with current in the first direction may be operative to actuate the latch pin from the first position to the second position. The coil powered with current in the second direction may be operative to actuate the latch pin from the second position to the first position. In some others of these teachings, the electromagnetic latch assembly include two coils, one for latching and the other for unlatching. The two coils may have windings in opposite directions. Employing two coil may allow for the control circuitry to be more robust. Employing only one coil may provide the most compact design.

According to some aspects of the present teachings, the rocker arm assembly is operative to cyclically break or vary the resistance of the electrical connection in relation to actuation of the cam follower. In some of these teachings, an internal combustion engine includes circuitry operative to determine the status of the electrical connection. The status of the electrical connection provides information that may be used to provide diagnostic feedback or to guide an engine control.

In some of these teachings, a surface of one of the parts forming the electrical connection is partially coated with a material that increases electrical resistance and the valvetrain is operable to move the area of contact between the two distinct parts between the coated surface and an uncoated surface, whereby the resistance of the connection varies in conjunction with rocker arm motion. In some of these teachings, one of the two distinct parts is operative to form a second electrical connection over a period when it is not forming the first electrical connection. In some of these teachings, the engine includes circuitry operative to determine the status of the second electrical connection. Determinations of the statuses of the first and second electrical connections may provide information that can be used to perform an engine management or diagnostic operation. In some of these teachings, one of these structures is used to perform an onboard diagnostic, which may result in a diagnostic report. In some of these teachings, one of these structures is used to provide information relating to whether the rocker arm is lifted at one or more particular times and an engine management operation is performed on the basis of that information.

Additional aspects of the invention relate to methods of powering or communicating with an electrical device mounted to a rocker arm assembly. The method includes powering or communicating with the electrical device through an electrical circuit that includes an electrical connection formed by abutment between the surfaces of two distinct parts and operating the rocker arm assembly in such a way that the surfaces move relative to one another. In some of these teachings, the electrical connection is preserved throughout operation of the rocker arm assembly. In some of these teachings, the electrical connection is episodically broken.

In some aspects of the present teachings, the rocker arm has external wiring that runs from the side of the rocker arm to the back of the rocker arm. A portion o an electromagnetic latch assembly including a coil may be installed in the rocker arm through the opening at the back. A latch pin may extend out of the rocker arm at the opposite side from the opening. In some of these teachings, wiring to the coil passes through the opening in the back of the rocker arm. In some of these teachings, external wiring running from the back of the rocker arm to the side of the rocker arm is supported by a part that is mounted within the opening in the back of the rocker arm. In some of these teachings, the part is press fit within that opening. In some of these teachings, the part is formed by over-molding the wiring. In some of these teachings, the part holds contact pads to the sides of the rocker arm. An electrical connection to the rocker arm may be made through the contact pads. The contact pads may have contact surfaces oriented in a plane. Rocker arm motion may be limited to directions all of which lie in a plane parallel to the plane in which the contact pads are oriented.

According to some aspects of the present teachings, the rocker arm assembly includes a pivot and a wiring connection to the rocker arm is made from a wiring harness that abuts the pivot. The pivot may be a hydraulic lash adjuster. Abutment with the pivot facilitates correct positioning of the wiring harness and connectors between the wiring harness and the rocker arm. In some of these teachings, the wiring harness abuts a plurality of pivots and provides connections to rocker arms associated with each of those pivots.

According to some aspects of the present teachings, the valvetrain includes a wiring harness providing power to the valvetrain. In some of these teachings the wiring harness connects to the power system of a vehicle. In some of these teachings the wiring harness connects to a vehicle control system. In some of these teachings, a wiring connection to the vehicle is made proximate a spark plug tower. In some of these teachings, the wiring runs through the valve cover proximate the spark plug tower. In some of these teachings, the wiring runs into the spark plug tower below the valve cover and out of the spark plug tower above the valve cover.

In some of these teachings, the wiring harness is supported by a frame. In some of these teachings, the frame is plastic. In some of these teachings, the wiring harness include wires that are fully enclose in the plastic frame. In some of these teachings, wires fully enclosed in the plastic frame are formed by strips of metal. The plastic frame may protect the wiring from the surrounding environment, prevent the wiring from contacting moving parts, and prevent the wiring from being damaged during maintenance.

In some of these teachings, the frame rests on the cylinder head. In some of these teachings, the frame is secured to the cylinder head. The frame may maintain the wiring in proximity to the cylinder head, where the wiring is out of the way. In some of these teachings, the frame supports or incorporates towers that include spring loaded connectors that slide over contacts on the rocker arms to complete electrical circuits that power the electromagnetic latch assemblies.

In some of these teachings, the frame abuts a spark plug tower. In some of these teachings, the frame has a circular opening that fits around a spark plug tower. In some of these teachings, the frame fits closely around a spark plug tower. These features may be provided to help locate the frame.

In some of these teachings, the frame abuts a pivot that provides a fulcrum for a rocker arm assembly. In some of these teachings, the pivot is a lash adjuster. The lash adjuster may be a hydraulic lash adjuster. The frame may mount against the pivot. In some of these teachings, the location of the frame is secured by the pivot. In some of these teachings, the location of the frame is secured by both a pivot and a spark plug tower. The frame may be braced against the pivot and the spark plug tower. Locating the frame against a pivot may facilitate properly positioning wiring and contacts that complete circuits with electronic devices mounted to the pivot or the rocker arm assembly.

According to some aspects of the present teachings, an electrical device mounted to a rocker arm is connected through a circuit that includes a wire that runs through a pivot providing a fulcrum for the rocker arm. In some of these teachings, the wire enters the pivot through a port designed to admit hydraulic fluid into the pivot. In some of these teachings, the wire runs upward through a passage within the lash adjuster. In some of these teachings, the wire exits the lash adjuster at a port suitable for providing hydraulic fluid from the hydraulic lash adjuster to a rocker arm that pivots on the hydraulic lash adjuster. In some of these teachings, the wire further passes through a passage in the rocker arm. In some of these teachings, the wire enters a chamber in the rocker arm designed as a hydraulic chamber. In this way, a hydraulic lash adjuster and or a rocker arm designed for hydraulic latching may be adapted to electrical latching with minimum modification. Moreover, the hydraulic lash adjuster and or the rocker arm may provide protective conduits for the wires. These locations may also be ones where the wires undergo relatively little movement in comparison to wires running to other parts of the rocker arm assembly.

The primary purpose of this summary has been to present certain of the inventors' concepts in a simplified form to facilitate understanding of the more detailed description that follows. This summary is not a comprehensive description of every one of the inventors' concepts or every combination of the inventors' concepts that can be considered "invention". Other concepts of the inventors will be conveyed to one of ordinary skill in the art by the following detailed description together with the drawings. The specifics disclosed herein may be generalized, narrowed, and combined in various ways with the ultimate statement of what the inventors claim as their invention being reserved for the claims that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a portion of an internal combustion engine including a valvetrain according to some aspects of the present teachings.

FIG. **2** is a cross-sectional view of a portion of the internal combustion engine of FIG. **1** with a cam on base circle.

FIG. **3** is a cross-sectional view of a portion of the internal combustion engine of FIG. **1** with a rocker arm assembly in a latched stated and a cam off base circle.

FIG. **4** is a cross-sectional view of a portion of the internal combustion engine of FIG. **1** with a rocker arm assembly in an unlatched stated with a cam off base circle.

FIG. **5** is a perspective view of a rocker arm assembly of the internal combustion engine of FIG. **1** with electrical connections according to some aspects of the present teachings.

FIG. **6** is a cross-section along line **6-6** of FIG. **5** showing an electrical connection according to some aspects of the present teachings.

FIG. **7** is an exploded view of the parts shown in FIG. **5**.

FIG. **8** is a schematic diagram of a circuit according to some aspects of the present teachings that may provide power to a rocker arm-mounted electrical device in the internal combustion engine of FIG. **1**.

FIG. **9** is a cross-sectional view of a portion of an internal combustion engine including a valvetrain according to some aspects of the present teachings.

FIG. **10** is a cross-sectional view of a portion of the internal combustion engine of FIG. **9** with a rocker arm assembly in a latched stated and a cam off base circle.

FIG. **11** is a schematic diagram of a circuit according to some aspects of the present teachings that may provide power to a rocker arm-mounted electrical device in the internal combustion engine of FIGS. **9** and **10**.

FIG. **12** is a schematic diagram of a circuit according to some aspects of the present teachings that may provide diagnostic information for a rocker arm assembly of the internal combustion engine of FIGS. **9** and **10**.

FIG. **13** is a cross-sectional view of a portion of an internal combustion engine including a valvetrain according to some aspects of the present teachings.

FIG. **14** is a schematic diagram of a circuit according to some aspects of the present teachings that may provide power to a rocker arm-mounted electrical device in the internal combustion engine of FIG. **13**.

FIG. **15** is a perspective view of a rocker arm assembly of the internal combustion engine of FIGS. **16** and **17**.

FIG. **16** is a cross-sectional view of a portion of an internal combustion engine including a valvetrain according to some aspects of the present teachings.

FIG. **17** is a cross-sectional view of a portion of the internal combustion engine of FIG. **16** with a rocker arm assembly in a latched stated and a cam off base circle.

FIG. **18** is a schematic diagram of a circuit according to some aspects of the present teachings that may provide power to a rocker arm-mounted electrical device in the internal combustion engine of FIGS. **16** and **17**.

FIG. **19** is a cross-sectional view of a portion of an internal combustion engine including a valvetrain according to some aspects of the present teachings.

FIG. **20** is a schematic diagram of a circuit according to some aspects of the present teachings that may provide power to a rocker arm-mounted electrical device in the internal combustion engine of FIG. **19**.

FIG. **21** is a schematic diagram of a variation on other circuits taught by the present disclosure, the variation providing communication with a rocker arm-mounted sensor mounted.

FIG. **22** is a rear view of a rocker arm assembly in a valvetrain according to some aspects of the present teachings.

FIG. **23** is a side view of the rocker arm assembly in the valvetrain of FIG. **22**.

FIG. **24** is a cross-sectional view of a portion of an internal combustion engine including a valvetrain according to some aspects of the present teachings.

FIG. **25** is a cross-sectional view of a portion of an internal combustion engine including a valvetrain according to some aspects of the present teachings.

FIG. **26** is a schematic diagram of a circuit according to some aspects of the present teachings that may provide power to a rocker arm-mounted electrical device in the internal combustion engine of FIG. **25**.

FIG. **27** is a cross-sectional view of a portion of an internal combustion engine including a valvetrain according to some aspects of the present teachings.

FIG. **28** is a cross-sectional view of a portion of an internal combustion engine including a valvetrain according to some aspects of the present teachings.

FIG. **29** is a perspective view of a portion of a valvetrain according to some aspects of the present teachings.

FIG. **30** is another perspective view of the valvetrain of FIG. **29**, this view including a cross-section of one of the rocker arm assemblies.

FIG. **31** is a partially exploded view illustrating the way in which contact pads are mounted to a rocker arm assembly of FIG. **29**.

FIG. **32** is an exploded view of a mounting frame for spring loaded contact pins which is part of the valvetrain illustrated in FIG. **29**.

FIG. **33** is an exploded view of a wiring harness according to some aspects of the present teachings.

FIG. **34** is a perspective view of a partially manufacture engine in which portions of a valvetrain including the wiring harness of FIG. **33** have been installed.

FIG. **35** is a perspective view of a portion of a valvetrain according to some aspects of the present teachings.

FIG. **36**. is a perspective view of a lead frame that holds spring loaded contacts in the valvetrain of FIG. **35**.

FIG. **37**. is a perspective view of one of the rocker arm assemblies in the valvetrain of FIG. **35**.

FIG. 38. is another perspective view of the valvetrain of FIG. 35.

FIG. 39. is perspective view of the valvetrain of FIG. 35 installed in an engine.

FIG. 40. is a perspective view of the rocker arm assembly of FIG. 37 fit with a contact frame.

FIG. 41. is a perspective view of the rocker arm assembly of FIG. 37 fit with a contact frame.

DETAILED DESCRIPTION

In the drawings, some reference characters consist of a number followed by a letter. In this description and the claims that follow, a reference character consisting of that same number without a letter is equivalent to a listing of all reference characters used in the drawings and consisting of that same number followed by a letter. For example, "permanent magnet **200**" is the same as "permanent magnet **200**A, **200**B". Permanent magnet **200** is therefore a generic reference that includes the specific instances permanent magnet **200**A and permanent magnet **200**B. Where options are provided for one instance subject to a generic reference, those options are to be given consideration in connection with all instances subject to that generic reference.

FIGS. **1-7** illustrate aspects an internal combustion engine **100**A that includes a cylinder head **102** and valvetrain **104**A in accordance with some of the present teachings. Referring to FIG. **1**, internal combustion engine **100**A may include a camshaft supporting member **117** and a camshaft **109** on which are mounted eccentrically shaped cams **107**. Camshaft supporting member **117** may be a cam tower formed into a cylinder head. In some of these teachings, camshaft supporting member **117** is a cam carrier. Valvetrain **104**A may include a plurality of rocker arm assemblies **106**A and pivots **140**. A mounting frame **132**A may mount to camshaft supporting member **117** and hold pogo pins **110**A adjacent and in abutment with contact pads **175**A on rocker arm assemblies **106**A. Mounting frame **132**A may include two members that are fixed together: a first member **134** that mounts to camshaft supporting member **117** and a second member **133** that holds pogo pins **110**A. Second member **134** may be made of plastic or another non-conductive material. A connection plug **174** may provide a convenient way to couple wires **173** from pogo pin connectors **110**A to an electrical system of internal combustion engine **100**A. Wires **173** and or connection plug **174** may also be attached to mounting frame **132**A.

With reference to FIGS. **2-4**, internal combustion engine **100**A may include a movable valve **152**, such as a poppet valve, which has a seat **156** within a combustion chamber **112** formed within cylinder head **102**. Rocker arm assembly **106**A may include inner arm **103**B and outer arm **103**A. Pivots **140** may be a hydraulic lash adjusters. A hydraulic lash adjuster (HLA) **140** may include an inner sleeve **145** and an outer sleeve **143**. A cam follower **111** may be mounted to inner arm **1036** and be configured to engage a cam **107** on camshaft **109** as camshaft **109** rotates. Rocker arm assembly **106**A is operative to transmit force from cam **107** to actuate valve **152**. An electromagnetic latch assembly **122** may be mounted to outer arm **103**A. Outer arm **103**A is mobile relative to cylinder head **102**.

Electromagnetic latch assembly **122** includes a coil **119**. Coil **119** may be rigidly mounted with respect to outer arm **103**A. Electromagnetic latch assembly **122** may include permanent magnets **120**A and **120**B, a latch pin **115**, and a shell **116**. Shell **116** may be made of a low coercivity ferromagnetic material such as soft iron. Permanent magnets **120**A and **120**B may be annular and arranged with confronting polarities and with a ring **121** of low coercivity ferromagnetic material between them. Latch pin **115** may include a latch head **118** and a low coercivity ferromagnetic portion **123**. Low coercivity ferromagnetic portion **123** may be a sleeve on an otherwise paramagnetic latch pin **115**. Latch pin **115** may be translatable between extended and retracted positions.

FIGS. **2** and **3** show latch pin **115** in the extended position. The extended position for latch pin **115** may be described as an engaging position and provides an engaging configuration for rocker arm assembly **106**A. If cam **107** is rotated off base circle while latch pin **115** is in the engaging position, head **118** of latch pin **115** may engage lip **113** of inner arm **1036**. The force of cam **107** on cam follower **111** may actuate cam follower **111** causing both inner arm **1036** and outer arm **103**A to pivot together on hydraulic lash adjuster **140**, bearing down on valve **152** and compressing valve spring **153**. Valve **152** may be lifted off its seat **156** as shown in FIG. **3** with a valve lift profile determined by the shape of cam **107**. The valve lift profile is the shape of a plot showing the height by which valve **152** is lifted of its seat **156** as a function of angular position of camshaft **109**. In the engaging configuration, camshaft **109** may do work on rocker arm assembly **106** as cam **107** rises off base circle. Much of the resulting energy may be taken up by valve spring **153** and returned to camshaft **109** as cam **107** descends back toward base circle.

If cam **107** is rotated while latch pin **115** is in the non-engaging position as shown in FIG. **4**, the downward force on cam follower **111** may be distributed between valve **152** and torsion springs **159**. Torsions springs **159** may be tuned relative to valve spring **153** such that torsion springs **159** yield in the non-engaging configuration while valve spring **153** does not. Inner arm **103**B may descend as torsion springs **159** wind and outer arm **103**A may remain in place. As a result, valve **152** may remain on its seat **156** even as cam **107** rotates. In the non-engaging configuration, camshaft **109** still does work on rocker arm assembly **106** as cam **107** rises off base circle. But in this case, most of the resulting energy is taken up by torsions springs **159**, which act as lost motion springs.

Hydraulic lash adjuster **140** may be replaced by another type of lash adjuster or by a static pivot. Lash adjustment may be implemented using a hydraulic chamber **144** that is configured to vary in volume as hydraulic lash adjuster **140** extends or contracts through relative motion of inner sleeve **145** and outer sleeve **143**. A supply port **146** in outer sleeve **143** may allow a reservoir chamber **142** to be filled from an oil gallery **128** in cylinder head **102**. The fluid may be engine oil, which may be supplied at a pressure of about 2 atm. When cam **107** is on base circle, this pressure may be sufficient to open check valve **141**, which admits oil into hydraulic chamber **144**. The oil may fill hydraulic chamber **144**, extending hydraulic lash adjuster **140** until there is no lash between cam **107** and roller follower **111**. As cam **107** rises off base circle, hydraulic lash adjuster **140** may be compressed, pressure in hydraulic chamber **144** may rise, and check valve **141** may consequently close.

Shell **116** may be formed by a plurality of pieces of low coercivity ferromagnetic material, which may be described as pole pieces in that they are operative within electromagnetic latch assembly **122** to guide magnetic flux from the poles of permanent magnets **120** or coil **119**. Rocker arm **103**A may be formed of low coercivity ferromagnetic material and that may perform all or part of this same function. Shell **116** may wrap around the outside coil **119** and may also wrap partially inside to provide stepped edges **129**. Low coercivity ferromagnetic portion **123** of latch pin **115** may be shaped to mate with stepped edges **129**. During actuation, magnetic flux from coil **119** may follow a circuit that crosses an air gap between a stepped edge **129** and latch pin **115**, in which case the stepped edge **129** may be operative to increase the magnetic forces through which latch pin **115** is actuated.

Electromagnetic latch assembly **122** may provide both extended and retracted positions in which latch pin **115** is stable. As a consequence, either the latched or unlatched configuration can be reliably maintained without coil **119** being powered. This may be advantageous when an electrical connection **108** is subject to interruption. Positional stability refers to the tendency of latch pin **115** to remain in and return to a particular position. Stability is provided by restorative forces that act against small perturbations of latch pin **115** from a stable position. Stabilizing forces may be provided by permanent magnets **120**. Each of the extended and retracted positions may provide low reluctance pathways for magnetic flux from each of the permanent magnets **120**. The reluctance of these pathways may be increased by small perturbations of latch pin **115** from a stable position. Alternatively, or in addition, one or more springs may be positioned to provide positional stability.

A conventional solenoid switch forms a magnetic circuit that includes an air gap, a spring that tends to enlarge the air gap, and an armature moveable to reduce the air gap. Moving the armature to reduce the air gap reduces the magnetic reluctance of that circuit. As a consequence, energizing a conventional solenoid switch causes the armature to move in the direction that reduces the air gap regardless of the direction of the current through the solenoid or the polarity of the resulting magnetic field. With electromagnetic latch assembly **122**, however, latch pin **115** may be moved in either one direction or another depending on the polarity of the magnetic field generated by coil **119**.

If coil **119** is energized with a direct current (DC) in a first direction, it may induce latch pin **115** to actuate from the extended position to the retracted position. The magnetic flux from coil **119** may reverse the magnetic polarity in low coercivity ferromagnetic elements such as shell **116**, ring **121**, and sleeve **123** that form low reluctance magnetic pathways through which permanent magnets **120** stabilize latch pin **115** in the extended position. That may greatly increase the reluctance of those magnetic circuits and cause magnetic flux from permanent magnets **120** to shift. The net magnetic forces on latch pin **115** may drive it to the retracted position.

While permanent magnets **120** may initially hold latch pin **115** in the extended position, at some point during latch pin **115**'s progress toward the retracted position, permanent magnets **120** begins to attract latch pin **115** toward the retracted position. At that point, the pathways for magnetic flux from permanent magnets **120** have shifted. Beyond that point, coil **119** may be disconnected from its power source and latch pin **115** may still complete its travel to the retracted position.

If coil **119** is energized with a current in a second direction, which is the reverse of the first direction, it may induce latch pin **115** to actuate from the retracted position to the extended position. The magnetic flux from coil **119** may reverse the magnetic polarity in low coercivity ferromagnetic elements forming magnetic circuits through which permanent magnets **120** stabilized latch pin **115** in the retracted position. That may greatly increase the reluctance of those magnetic circuits and cause magnetic flux from permanent magnets **120** to shift again. The net magnetic forces on latch pin **115** may drive it to the extended position. At some point during latch pin **115**'s progress toward the extended position, permanent magnets **120** begin to attract latch pin **115** toward the extended position. Accordingly, at some point during latch pin **115**'s progress, coil **119** may be disconnected from its power source and latch pin **115** may still complete its travel to the extended position.

As used herein, a permanent magnet is a high coercivity ferromagnetic material with residual magnetism. A high coercivity means that the polarities of permanent magnets **120** remain unchanged through hundreds of operations through which electromagnetic latch assembly **122** is operated to switch latch pin **115** between the extended and retracted positions. Examples of high coercivity ferromagnetic materials include compositions of AlNiCo and NdFeB.

Coil **119** may be powered through an electrical circuit **105**A that includes one or more electrical connections **108**A formed by contact between pogo pins **110**A and contact pads **175**A. FIG. **8** provides a schematic diagram for an example electrical circuit **105**A that also includes an H-bridge **177**. H-bridge **177** may include diodes **190** and switches **191** that can be operated through signals **192** to selectively apply voltage from a power source **176** to coil **119** with current flowing in either a first or a second direction. One polarity may be used when it is desired to actuate latch pin **115** to the extended position and the other polarity may be used when it is desired to actuate latch pin **115** to the retracted position. The potential of ground **172** may be the potential of cylinder head **102**. An alternative circuit **105**A could be made operative to selectively couple coil **119** with one of two power sources, one source having a potential above ground **172** and the other below ground **172**. In this alternative circuit structure, a single electrical connection **108**A may be used to provide coil **119** with power for current in either direction while a connection to ground **172** may be formed through the structure of valvetrain **104**A.

In some alternative embodiments, electromagnetic latch assembly **122** includes two coils **119** isolated from one-another, one with coils wound in a first direction and the other with coils wound in the opposite direction. Two circuits **105**A with electrical connections **108** may then be used to power electromagnetic latch assembly **122**. One of the circuits **105**A may be closed to actuate latch pin **115** in a first direction and the other to actuate latch pin **115** in the reverse direction.

The portion of circuit **105**A that includes electrical connection **108**A is electrically isolated from ground **172** and cylinder head **102**, which may be at the same potential. Electrical connection **108**A may be made by surface contact between pogo pin **110**A and contact pad **175**A. Contact pad **175**A may be mounted to but insulated from rocker arm **103**A. Contact pad **175**A may at times move in response to rotation of cam **107** by virtue of contact pad **175**A being mounted to outer arm **103**A. Accordingly, rocker arm assembly **106**A is operative to cause the abutting surfaces of pogo pin connector **110**A and contact pad **175**A that form electrical connection **108**A to shift and move relative to one another as cam **107** rotates. Different types of abutting structures could replace contact pad **175**A and pogo pin connector **110**A.

With reference to FIG. **6**, pogo pin connector **110**A may include a spring **178**, an extending member **179**, and a housing member **180**. Spring **178** may be configured to bias extending member **179** outward from housing member **180** with the effect of providing a force that tends to lengthen pogo pin connector **110**A and maintain extending member

179 in contact with an opposing surface such as a surface of contact pad 175A. Extending member 179 is conductive. Housing member 180 may be conductive. Spring 178 may also be conductive. Accordingly, current through extending member 179 may flow though spring 178, housing member 180, or both.

Rocker arm 103A is operative to pivot on HLA 140, which provides a fulcrum. The motion of rocker arm 103A is substantially constrained to a plane parallel to an axis on which rocker arm 103A pivots. Contact pad 175A may provide a relatively flat surface having a surface normal vector that is substantially parallel to that pivot axis. That geometry allows pogo pin connector 110A to remain substantially stationary while sliding over and continuously abutting contact pad 175A even as rocker arm 103A undergoes the pivoting movement. Pogo pin connector 110A may be fit with a roller and roll over contact pad 175A as rocker arm 103A pivots.

Contact pad 175A may be mounted over a spring post of rocker arm 103A. A spring post is a part of rocker arm 103A around which torsion spring 159 winds. With reference to FIG. 5, torsion springs 159 are mounted on hubs 149, which fit over the spring posts 157 (shown in the example of FIG. 23, but not in the example FIG. 5). Mounting frame 132A may hold pogo pin connector 110A in a substantially fixed position relative to cylinder head 102. Pogo pin connector 110A could be otherwise held in a substantially fixed position relative to cylinder head 102. Alternatively, pogo pin connector 110A could be mounted to outer arm 103A and contact pad 175A could be held to mounting frame 132A.

FIGS. 22-23 illustrate an internal combustion engine 100K including a rocker arm assembly 106K that, like the rocker arm assembly 106A of engine 100A, has an electrical connection 108 formed by abutment between a part 110 mounted to a rocker arm 103 and a part 175 mounted to a part distinct from that rocker arm 103. In both these examples, the part 110 mounted to the rocker arm 103 may be mounted over, and optionally attached to, a spring post 157 of the rocker arm 103.

In engine 100K, an electrical connection 108K may be formed between contact pins 175K mounted to rocker arm 103A and motor brushes 110K mounted to a part distinct from rocker arm 103A. Motor brushes 110K may be held by a mounting frame 132K in a position where they are biased against and slide over contact pins 175K. Frame 132K is itself mounted to HLA 140. Frame 132K may extend to encompass a plurality of HLAs 140, which may facilitate holding mounting frame 132K in a fixed position. A wiring harness 168 may be held by frame 132K. Wiring harness 168 may include a plurality of wires 173 that connect to motor brushes 110K, whereby wiring harness 168 may carry power or communication signals for coil 119 or other electrical devices on a plurality of rocker arm assemblies 106K.

With reference to FIGS. 22 and 23, mounting a part 175 over a spring post 157 may place that part proximate a pivot axis 169 of rocker arm 103A. As a consequence of that proximity, the motor brushes 110K and contact pin 175K that form electrical connection 108K undergo relatively little relative motion as rocker arm 103A moves through its range of motion. That may facilitate maintaining electrical connection 108K continuously.

While the top of HLA 140 may be approximately hemispherical or cylindrical and the mating surface of rocker arm 103A may have an approximately corresponding shape, either of these surfaces may deviate to some degree from any such idealized shape or perfect correspondence. As a result, the movement of rocker arm 103A may not be precisely restricted to a simple pivoting motion and the location of pivot axis 169 may not be exactly and uniquely determined. These types of variations from the ideal that are common in rocker arm assemblies and the resulting uncertainties in location of pivot axis 169 are negligible for purposes of the present disclosure.

FIGS. 9-10 illustrate an internal combustion engine 100B that includes a valvetrain 1046 having a rocker arm assembly 1066. Coil 119 of rocker arm assembly 106B may be powered through an electrical circuit 105B for which FIG. 11 provides an example. Electrical circuit 105B may include an electrical connection 108B formed between brushes 110B and contact pad 175B. Contact pad 175B may be mounted to rocker arm 103A.

Electrical circuit 105B may include power sources 176A and 176B. One of these sources may provide a voltage above the potential of cylinder head 102 while the other provides a voltage below the potential of cylinder head 102. Cylinder head 102 may be operative as a ground. Switches 191A and 191B may be operated through control signals 192A and 192B to selectively couple one or the other of sources 176A and 176B to a first pole of coil 119. Wire 196 may connect a second pole of coil 119 to rocker arm 103A, which may be electrically coupled to cylinder head 102 through the structure of valvetrain 104B including outer arm 103A and HLA 140. Alternatively, rocker arm assembly 106B may be provided with two electrical connections 108B and coil 119 may be powered through a circuit like electrical circuit 105A.

Valvetrain 104B may be operative to move rocker arm 103A through a range of motion. That range of motion may include a first portion over which connection 108B is closed and a second portion over which electrical connection 108B is open. Within at least the portion of the range of motion over which connection 108B is closed, the motion of rocker arm 103B may move contact pads 175B in a direction that is substantially perpendicular to the orientation of brushes 110B. Brushes 110B may therefore bend and slide over the surfaces of contact pads 175B. Brushes 110B may be of a type used in motors.

Surfaces adjacent the conducting surface of contact pad 175B may be insulated so that electrical circuit 105B is opened and closed as electrical connection 108B is opened and closed. Electrical circuit 105B may be monitored to detect the forming and breaking of electrical connection 108B. This information may be used to monitor the motion of rocker arm 103A. That information may be useful in making diagnostic determinations, which may be reported. Alternatively, that information may be used for engine management.

A current measuring device 193 may be provided to detect the forming and breaking of electrical connection 1086. As illustrated in FIG. 11, current measuring device 193 may include a shunt resistor 194 configured within electrical circuit 1056 and a voltage measuring device 195 connected across shunt resistor 194. Another alternative for current measuring device 193 is an inductive coil configured to measure current in circuit 105B.

In some aspects of the present teachings, a second contact pad 175C is also mounted to rocker arm 103A. As shown in FIG. 10, over a portion of rocker arm 103A's range of motion, brushes 1106 may make brush against contact pad 175C to form an electrical connection 108C, completing a circuit 105C for which FIG. 12 provides an example. The portion of rocker arm 103A's range of motion over which brushes 1106 abut second contact pad 175C to form electrical connection 108C may be disjoint from that portion over which brushes **1106** make contact with contact pad **1756** to form electrical connection **108**B. A resistor **182** may be positioned to connect between second contact pad **175**C and a ground, such as cylinder head **102**. Resistor **182** may be selected to be the principal source of resistance in circuit **105**C.

A voltage may be applied to circuit **105**C at a time when actuation of latch pin **115** is not desired. The voltage may be from source **176**A, source **176**B, or some other source. In some of these teaching, that voltage is selected to be of the wrong polarity to induce motion of latch pin **115** from its current position. In some of these teaching, that voltage is less than a voltage required to actuate latch pin **115**. Given the resistance of circuit **105**C and the magnitude of the applied voltage, a current of predictable magnitude may flow through circuit **105**C but only at such times that electrical connection **108**C is closed. The presence or absence of that current may be detected by current measuring device **193** and that detection used to monitor the motion of rocker arm **103**A and make diagnostic determinations on the basis thereof.

Contact pads **175**B and **175**C are mounted to rocker arm **103**A on a projecting structure **151**. Projecting structure **151** supports contacts pads **1756** and **175**C on a surface **150** that has a normal vector **136** that points approximately directly away from the approximate axis **169** about which rocker arm **103**A pivots. "Points approximately directly away" means that a line through normal vector **136** would come close to intersecting axis **169**. The radius of curvature of surface **150** is approximately equal to its distance from pivot axis **169**. As a result of these two conditions, the distance from the base of motor brushes **1106** and surface **150** remains nearly constant as rocker arm **103**A pivots through it range of motion. This structure facilitates motor brushes **1106** making contact first with contact pad **1756** and then with contact pad **175**C as rocker arm **103**A pivots through it range of motion. If contact pad **1756** were extended along surface **150**, this same structure could be used to maintain contact between motor brushes **1106** and contact pad **1756** throughout the range of motion of rocker arm **103**A.

FIG. **24** illustrates an internal combustion **100**J that uses a similar structure to maintain a connection **108**J between a roller **175**J mounted to rocker arm assembly **106**J and a contact pad **110**J. Contact pad **110**J may be held by frame **211** to a camshaft support member **117**, which may be a cam carrier. Contact pad **110**J has a surface with a radius of curvature approximately equal to its distance from pivot axis **169** and a surface normal vector **136**B oriented approximately in the direction of pivot axis **169**. This direction need not be the shortest distance to pivot axis **169**, but may approximately intersect pivot axis **169** with some angle of incidence. This structure allows roller **175**J to remain in abutment with contact pad **110**J even as rocker arm **103**A moves through its range of motion. Roller **175**J may be biased against contact pad **110**J by a spring (not shown) to maintain contact while allowing some upward and downward motion of rocker arm **103**A for lash adjustment.

FIG. **13** illustrates an internal combustion engine **100**D that includes a valvetrain **104**D having a rocker arm assembly **106**D. Rocker arm assembly **106**D includes a rocker arm **103**A on which may be mounted an electromagnetic latch assembly **122** that includes coil **119**. Coil **119** may be powered through an electrical connection **108**D that may be formed within an interface region **154** where rocker arm **103**A contacts and pivots on HLA **140**. A pair of electrical connections **108**D may be provided side-by-side at this location to form an electrical circuit **105**D as illustrated in FIG. **14**. Rocker arm **103**A and HLA **140** are (mechanical) load-bearing members of valvetrain **104**D. Other examples of load-bearing members of valvetrain **104**D include elephant's foot **101**, roller follower **111**, roller bearings **114** and their bearing races, latch pin **115**, poppet valve **152**, axle **155**, and torsion springs **159**.

Electrical connections **108**D may be formed by surface contact between first parts **110**D mounted to HLA **140** and second parts **175**D mounted to rocker arm **103**A. Parts **110**D may be insulated from surrounding areas of HLA **140**. An insulating layer **171** may insulate part **175**D from surrounding areas of rocker arm **103**A. One or both of parts **110**D and **175**D may be sprung to bias them into contact. In one example, parts **175**D are spring clips. In another example, parts **110**D are pogo pin connectors. Both parts **175**D and **110**D may include sprung members biasing them into contact. Insulating layer **171** may be formed from any suitable material.

Engine **100**D has wires **173** that form part of electrical circuit **105**D entering HLA **140** through a port **183** and running upward to rocker arm **103**A through a passage **184** within HLA **140**. Wires **197**, which form another part of circuit **105**D, run through a hydraulic passage **189** in rocker arm **103**A. Port **183** may be a port designed to admit hydraulic fluid from cylinder head **102** into HLA **140**. The chamber within rocker arm **103**A that houses electromagnetic latch assembly **122** may have been designed as a hydraulic chamber for a hydraulic latch. The interface **154** between HLA **140** and rocker arm **103**A may have been designed to form a seal and allow the transfer of hydraulic fluid from passage **184** to passage **189**. Running wires in these locations can be useful even if sliding electrical connection **108**D is replaced by a fixed connection or a continuous run of wire.

Engine **100**D is an example in which an electrical connection **108** is formed by abutment between a first part **110** mounted to or forming part of a hydraulic lash adjuster **140** and another part **175** mounted to of forming part of a rocker arm **103**. Engine **100**G of FIG. **25** provides another example. Engine **100**G is also an example in which a rocker arm assembly **106**G includes a hydraulic lash adjuster **140**G that may be electrically isolated from cylinder head **102** and form part of a circuit **105**L through which an electrical device, such as electromagnetic latch assembly **122**, mounted to a rocker arm **103**A may be powered. FIG. **26** provides a diagram for an example circuit **105**L.

Hydraulic lash adjuster **140**G may be insulated from cylinder head **102** by an insulating sleeve **201**. Alternatively, a non-conductive coating may be used in place of sleeve **201**. Hydraulic lash adjuster **140**G may be insulated from rocker arm **103**A by insulating cup **199**. Insulating cup **199** may be load-bearing and constructed of any suitable material. A suitable material may be, for example, a ceramic such as SiC or a polymer such as an epoxy. Insulating cup **199** may be replaced by a similar structure formed into HLA **140**G. An electrically insulating coating may be used in place of either of these structures.

Inner sleeve **145** and or outer sleeve **143** of HLA **140**G may be left free to rotate within the bore **138** in cylinder head **102** to reduce wear at the interface with rocker arm **103**A. On the other hand, it may be desirable to restrict rotation of insulating sleeve **201** so that it may provide a stationary support for a wire **173**. A conductive ring **203** may be used to form an electrical connection between wire **173** and outer sleeve **143** while permitting relative rotation between outer sleeve **143** and insulating sleeve **201**. Besides electrical connection **108**L, circuit **105**L includes sliding contact between conductive ring **203** and outer sleeve **143** and sliding contact between outer sleeve **143** and inner sleeve **145**

A leaf spring **175**L formed of one or more ribbons of metal may be mounted to outer arm **103**A and form electrical connection **108**L by sliding contact with inner sleeve **145**, also referred to as part **110**L in this example. Brushes or another type of structure could be used in place of leaf spring **175**L to make contact between the portion of circuit **105**L that is mounted to rocker arm **103**A and the portion of circuit **105**L that is mounted to or part of HLA **140**G. In some of these teachings, the contact is made with the top of inner sleeve **145**. Such a contact could be placed underneath the insulating cup **199**. Alternatively, rocker arm **103**A could be electrically isolated from cylinder head **102** and electrical connection **108**L could be made by direct contact between HLA **140**G and rocker arm **103**A. Another connection **108** formed by abutment could be used for a ground connection.

Mounting wires **173** to HLA **140** may provide several advantages. One advantage is that HLA **140** may provide a relatively stationary location to mount wires, particularly an HLA **140**G fit with a sleeve **201** that is prevented from rotating. Another advantage is that HLA **140** provides a location to mount a part **110** in which it has a well-controlled spatial relationship to another part **175** that may be mounted to a rocker arm **103**. The parts **110** and **175** may then be configured to abut and form electrical connection **108**. Engine **100**M of FIG. **27** and engine **100**N of FIG. **28** provide additional examples demonstrating this concept.

With reference to FIG. **27**, an electrical connection **108**M is formed by abutment between part **110**M mounted to HLA **140**G and part **175**M mounted to rocker arm **103**A. Part **110**M is a spring, brush or other structure with sufficient resilience to bend when deformed by movement of rocker arm **103**A but spring back to maintain contact with part **175**M when the movement is reversed.

With reference to FIG. **28**, a spring, brush or other structure **175**N that is mounted to rocker arm **103**A is biased against a conductive ring **110**N mounted to the outside of insulating sleeve **201** in order to form the connection **108**N. A rod **209** or other structure may extend from rocker arm **103**A to support structure **175**N in proximity to HLA **140**G. Structure **175**N may have sufficient resilience to maintain electrical connection **108**N throughout the motion of rocker arm **103**A.

FIGS. **16-17** illustrate an internal combustion engine **100**E that includes a valvetrain **104**E having a rocker arm assembly **106**E. FIG. **15** provides a prospective view of rocker arm assembly **106**E. Rocker arm assembly **106**E may be a switching rocker arm including an inner arm **103**D and an outer arm **103**C. A cam follower **111** mounted to inner arm **103**C may be configured to engage cam **107**. Cam followers **198**, which may be sliders, may be configured to engage additional cams (not shown) to provide an alternate valve lift profile from the one provided by cam **107**. An electromagnetic latch assembly **122** having a coil **119** may be mounted to inner arm **103**D.

Referring to FIGS. **16-18**, coil **119** may be powered through an electrical circuit **105**E that includes an electrical connection **108**E that is formed between a conductive inlay **175**E in valve **152** and pogo pin **110**E mounted to cylinder head **102**. Valve **152** is a load-bearing member of valvetrain **104**E. Valve **152** transmits force between rocker arm **103**D and valve spring **153**.

FIG. **18** provides a schematic diagram for an example electrical circuit **105**E. A part of electrical circuit **105**E may be formed by a ribbon or coil of metal **188** making a connection between conductive inlay **187** and coil **119** mounted to inner arm **103**D. Ribbon or coil of metal **188** may be relatively stiff. Coil **119** may be grounded to inner arm **103**D.

As shown in FIGS. **16** and **17**, as valve **152** opens and closes, pogo pin **110**E may slide up and down valve **152** while remaining in contact with conductive inlay **175**E and keeping electrical connection **108**E closed. Pogo pin **110**E may be replaced by another type of part suitable for sliding along conductive inlay **175**E while maintaining an electrical connection. Alternatives include, without limitation, motor brushes and spring clips. An alternative to conductive inlay **175**E is a conductive trace on the surface of valve **152**. Another alternative is to insulate valve **152** where it makes contact with other metal parts, whereby the body of valve **152** may be part of electrical circuit **105**E. In each of these examples, a portion of electrical circuit **108**E is rigidly coupled to and disposed along the length of the stem of valve **152**.

FIG. **19** illustrates an internal combustion engine **100**F that includes a valvetrain **104**F having a rocker arm assembly **106**F. An electromagnetic latch assembly **122** including coil **119** may be mounted to inner arm **103**D of rocker arm assembly **106**F. Coil **119** may be powered through an electrical circuit **105**F, for which FIG. **20** provides an example schematic diagram. Camshaft **109** may be mounted on dielectric bearings (not shown). Cam roller **111** may be mounted on dielectric bearings **114**E. Circuit **105**F connects coil **119** to power source **176** through brushes **110**F, camshaft **109**, cam **107**, cam roller **111**, and brushes **110**G. Circuit **105**E includes camshaft **109**, cam **107**, and cam roller **111**, which may be maintained at potentials above or below that of cylinder head **102**.

Electrical circuit **105**F includes three connections formed by abutting surfaces of distinct parts that undergo relative motion in connection with actuation of cam follower **111**. These are electrical connection **108**F formed between camshaft **109** and brushes **110**F, electrical connection **108**H formed between cam **107** and cam roller **111**, and electrical connection **108**G formed between cam roller **111** and motor brushes **110**G, which may be mounted to inner arm **103**D.

The internal combustion engines **100** all have end pivot overhead cam (OHC) type valvetrains **104**. But the present teaching are generally applicable to internal combustion engines having other types of valvetrains **104** including, for example, other types of OHC valvetrains and overhead valve (OHV) valvetrains. As used in the present disclosure, the term "rocker arm assembly" may refer to any assembly of components that is structured and positioned to actuate a valve **152** in response to rotation of a camshaft **109**.

Electrical circuits **105** formed with electrical connections **108** may be used to power or communicate with any suitable type of electronic device mounted to a rocker arm assembly **106**. FIG. **21** provide a diagram for an example electrical circuit **105**H including an electrical connection **108** through which a sensor **185** mounted to a mobile portion of a rocker arm assembly **106** may communicate with a device mounted to a part distinct from rocker arm assembly **106**, such as an engine control unit (ECU) **186**. That information may be used for diagnostics or control. In some of these teachings, sensor **185** is a device that does not require external power. Sensor **185** may be, for example, an accelerometer.

FIG. **29-32** illustrates parts of another valvetrain **400** suitable for engine **100**. As shown in FIG. **29**, valvetrain **400** includes at least two rocker arm assemblies **406** that are generally similar to rocker arm assemblies **106**. With further reference to FIGS. **30** and **31**, rocker arm assemblies **406** include an outer arm **103**A, an inner arm **103**B, and contact pads **404**A and **404**B held to one side of outer arm **103**A over spring post **157**.

Valvetrain **400** further includes a framework **420**A that holds spring loaded pins **407**A and **407**B against contact pads **404**A and **404**B respectively, at least when rocker arm **103**A is on base circle. As shown in FIG. **32**, framework **420**A includes a base plate **414** and slip ring towers **415**A that hold spring loaded pins **407** in abutment with contact pads **404**. The abutment completes a circuit that provides power to a coil **119** that is operative to actuate latch pin **115**. Contacts pads **404**, coil **119**, and latch pin **115** are all mounted to outer arm **103**A. Wires **413** couple coil **119** to contact pads **404**.

With reference to FIG. **31**, contact pads **404**A and **404**B have planar contact surfaces **405**A and **405**B respectively. Each rocker arm assembly **406** pivots on a pivot **140**. Outer arm **103**A and inner arm **1036** are free to pivot relative to one-another except when they are engaged by latch pin **115**. Pivot **140** may raise or lower rocker arm assembly **406** to adjust lash. These motions take rocker arm **103**A in directions parallel to the plane in which the planar contact surfaces contact pads **404**A and **404**B are oriented. Accordingly, the connections between contacts pads **404** and spring-loaded pins **407** may be maintained as outer arm **103**A goes through its range of motion.

In some of these teachings, spring loaded pin **407**B remains in abutment with contact surface **405**B throughout rocker arm **103**A's range of motion. In some of these teachings, spring loaded pin **407**A remains in abutment with contact surface **405**A through only a portion of rocker arm **103**A's range of motion. Contact pad **404**A may be structured and positioned such that as rocker arm **103**A is lifted off base circle, spring loaded pin **407**A moved from abutment with contact surface **405**A to abutment with contact surface **405**C. Connection through contact surface **405**C may present a distinctly higher resistance than connection through contact surface **405**A. The higher resistance may be provided by a coating on contact surface **405**C that is not present on contact surface **405**A. In some of these teachings, that coating is a diamond-like carbon (DLC) coating. The difference in resistance may be used to detect the position of rocker arm **103**A.

Latch pin **115** may be installed in rocker arm **103**A through opening **408** at the back of rocker arms **103**A. Coil **119** is also installed in rocker arm **103**A through opening **408**. Wires **413**, which couple coil **119** to contact pads **404**, run out of rocker arm **103**A through opening **408**. Wires **413** continue around the side of rocker arm **103**A to connect with contact pads **404**. In some of these teachings, wires **413** and contact pads **404** are supported by a bracket **409** that mounts to rocker arm **103**A within opening **408**.

As shown in FIG. **31**, bracket **409** may include a part **411** held at the back of rocker arm **103**A and a part **412** held to the side of rocker arm **103**A. In some of these teachings, however, parts **411** and **412** are provided as a single part. In some of these teachings, that single part is formed by over-molding wires **413** and contact pads **404**. Bracket **409** may be press fit into opening **408**.

As shown in FIG. **32**, base plate **414** may include cutouts **424** that fit around pivots **140**. When framework **420** is installed in engine **100**, baseplate **414** may rest atop cylinder head **102** and abut two pivots **140**. Cutouts **424** may cooperate with pivots **140** to ensure proper positioning of framework **420** with respect to rocker arm assemblies **406** and therefore proper position of spring loaded pins **407** with respect to contact pads **404**. Framework **420** may be secured to cylinder head **102** by bolts passing through openings **416**.

FIG. **33** illustrates a mounting frame **420**B that may be used instead of mounting frame **420**A. Mounting frames **420** may be made of plastic. Mounting frame **420**B includes an opening **422** that may fit closely around a spark plug tower (not shown) when mounting frame **420**B is installed on a cylinder head **102**. FIG. **34**. shows mounting frame **420**B installed on cylinder head **102** with opening **422** positioned above an opening **429** in cylinder head **102** for a spark plug tower. The spark plug tower may be installed before or after frame **420**B. Mounting frame **420**B may also include four semi-circular cutouts **424** that fit against pivots **140**. When engine **100** is fully assembled with frame **420**B, a spark plug tower fits through opening **422**, cutouts **424** abut pivots **140**, and the position of frame **420** is thereby secured. The position of frame **420** may be further secured by fastening frame **420** to cylinder head **102**.

As shown in FIG. **33**, mounting frame **420**B includes an upper part **425** and a lower part **426** that may be fastened together around wires **427** to provide a wiring harness in which wires **427** are isolated from the surrounding environment. Slip ring towers **415**B may be attached to frame **420**B. Alternatively, frame **420**B may include slip ring towers **415**B as part of a unitary structure. Slip ring towers **415**B support spring loaded pins **407** that make electrical connections between wires **427** and contact pads **404**.

As shown in FIG. **34**, frame **420**B provides a connection plug **428** adjacent an opening **429** for a spark plug tower. Plug **428** is for connecting wires **427** to a vehicle power system. The wires from plug **428** may pass through the valve cover (not shown) adjacent the spark plug tower (not shown). Alternatively, those wires may enter the spark plug tower below the valve cover and exit the spark plug tower above the valve cover. A valve actuation module according to the present teachings may be formed by temporarily securing pivots **140** and rocker arm assemblies **406** to frame **420**. The valve actuation module is easily installed in engine **100**.

FIGS. **35-40** illustrate parts of a valvetrain **1040** according to some aspects of the present teachings. FIGS. **35** and **36** provide perspective views of a portion of the valvetrain **1040** that includes two rocker arm assemblies **1060**, two pivots **140**, and a power transfer module **223**. A power transfer module, as the term is used in the present disclosure, is a structure that includes an electrical contact and a mounting frame that holds an electrical contact in position adjacent a rocker arm assembly. Power transfer module **223** is shown separately in FIG. **36**. A rocker arm assembly **1060** is shown separately in FIG. **37**. FIG. **39** illustrates parts of valvetrain **1040** installed is engine **100**. Pivots **140**, which may be hydraulic lash adjusters, provide fulcrums for rocker arm assemblies **1060**.

Rocker arm assemblies **1060** each include two pivotally connected rocker arms **103**E and **103**F. As shown in FIG. **28**, electromagnetic latch assemblies **122** are installed in outer rocker arms **103**E. Electromagnetic latch assemblies **122** includes a coil **119** that receives power via contact pins **212**, which are mounted to and held one on each side of rocker arm **103**E.

Power transfer module **223** includes leaf springs **215**. Leaf springs **215** are electrical conductors. Power transfer module **223** is designed to hold leaf springs **215** in abutment with contact pins **212**. Electrical connections through which coil **119** may be powered are made between contact pins **212** and leaf springs **215**. There may be two electrical connection to each rocker arm **103**E, the two connections being made on opposite sides of the rocker arm **103**E. Electrical contact may be maintained even as contact pins **212** slide over the surfaces of leaf springs **215** in connection with normal operation of rocker arm assemblies **1060**.

Rocker arm assemblies **1060** are configured to undergo a pivoting motion as they are actuated by cams **107** (see FIG. **38**). This pivoting occurs approximately on an axis. In some of these teachings, contact pins **212** are located proximate that axis to keep the relative motions between contact pins **212** and leaf springs **215** small. The range of motion cams **107** induce on contact pins **212** may be 10% or less the range of motion cams **107** induce on parts of rocker arm assemblies **1060** most distant from the axis. In some of these teachings, the range of motion for contact pins **212** is 2% or less the motion induced on the parts of rocker arm assemblies **1060** most distant from the axis.

On the other hand, in some of these teachings, a certain range of motion between contact pins **212** and leaf springs **215** is desirable. A portion of the surface of a leaf spring **215** may be coated with a material that significantly increase the resistance of an electrical circuit comprising a connection between contact pin **212** and leaf spring **215**. Contact pin **212** may move to that high resistance surface only when cam **107** is lifting rocker arm **103**E. The increase in resistance may be detected and used to provide rocker arm position information, which in turn may be used in diagnostic or control operations.

As can be seen in FIG. **36**, leaf springs **215** have an outwardly bowed portion **221** adapted to flex against contact pin **211**. Power transfer module **223** may be adapted to maintain the bowed portion **221**. These adaptations may include structures that hold leaf spring **215** above and below the bowed portion **221**. In some of these teachings, power transfer module **223** is over-molded around leaf spring **215**, wherein the over-molding secures leaf spring **215** to power transfer module **223**.

A connection plug **219** may be positioned at the top of power transfer module **223**. Connection plug **219** may be used to couple power transfer module **223** to a vehicle's electrical system. An elevated location such as this, which may be above the heights of rocker arm assemblies **1060**, facilitates the coupling with the vehicle's electrical system in that wires connecting to connection plug **219** have a short distance to travel before passing through the valve cover (not shown). The wires may pass through the valve cover adjacent a spark plug tower. One option is to run the wires into and out of a spark plug tower in order that they pass through the valve cover within a spark plug tower.

Power transfer module **223** has a lower portion **241** that rests against cylinder head **102** adjacent pivot **140** and an upper portion **243** that fits over and may rest on a raised portion **245** of cylinder head **102**. Raised portion **245** may be above rocker arm assembly **106**. "Above" is used in the sense that rocker arm assembly **1060** is "above" a combustion chamber formed within cylinder head **102**. Power transfer module **223** has openings **239** that fit around pivots **140**. Openings **239** abut pivots **140** and help locate power transfer module **223**. Openings **239** may fit tightly around pivots **140**, whereby pivots **140** may by joined to power transfer module **223** prior to installation. Openings **233** may be formed in lower portion **241** of power transfer module **223** and used to bolt power transfer module **223** to cylinder head **102**.

FIG. **40** shows rocker arm **106**B together with a contact frame **224** that supports contact pins **212** and electrical connections between coil **119** and contact pins **212**. The electrical connections are preferably made with stamped metal leads **225**. Leads **225** may be joined to contact pins **212** at one end and coil ties off pins at the other. Stamped metal leads **225** may be press fit around or soldered to the pins.

Contact frame **224** may be press fit with an opening **226** through which electromagnetic latch assembly **122** is installed within rocker arm **103**E. Contact frame **224** may also be held to the sides of rocker arm **103**E. In this example, contact frame **224** is bolted to the sides of rocker arm **103**E. Alternatively, support at the sides of rocker arm **103**E may be provided by piloting contact pins **212** to the sides of rocker arm **103**E. Insulation may prevent short circuiting between a contact pin **212** and rocker arm **103**E although this structure without insulation could be used to form a connection to ground.

FIG. **41** provides a flow chart of a method **900** according to some aspects of the present teachings that may be used to operate internal combustion engine **100**. Method **900** begins with action **901**, holding latch pin **115** in a first position using a magnetic field generated by a first permanent magnet **200**A and following a magnetic circuit **163** that encircles the windings of coil **119**. Such a magnetic circuit may include a segment passing through coil **119** and a segment that is outside coil **119**. The first position may correspond to either an extended or a retracted position for latch pin **115**. In some of these teachings, action **901** further includes holding latch pin **115** in the first position using a magnetic field generated by a second permanent magnet **200**B and following a shorter magnetic circuit **165** that does not encircles the windings of coil **119**.

Method **900** continues with action **903**, energizing coil **119** with a current in a forward direction to alter the circuit taken by flux from first permanent magnet **200**A and cause latch pin **115** to translate to a second position. Energizing coil **119** with a current in a forward direction may also alter the circuit taken by flux from a second permanent magnet **200**B. Action **903** may be initiated by an automatic controller. In some of these teachings, the controller is an ECU.

Following translation of latch pin **115** to the second position through action **903**, coil **119** may be disconnected from its power source with action **905**. Method **900** then continues with action **907**, holding latch pin **115** in the second position using a magnetic field generated by a first permanent magnet **200**A and following a magnetic circuit **162** that does not encircles the windings of coil **119**. This may be a short magnetic circuit with low magnetic flux leakage. In some of these teachings, action **907** further includes holding latch pin **115** in the second position using a magnetic field generated by a second permanent magnet **200**B and following a magnetic circuit **164** that encircles the windings of coil **119**.

Method **900** may continue with action **909**, energizing coil **119** with a current in a reverse direction to again alter the circuit taken by flux from first permanent magnet **200**A. Action **909** causes latch pin **115** to translate back to the first position. Energizing coil **119** with a current in a reverse direction may also alter the circuit taken by flux from a second permanent magnet **1906**. Action **909** also may be initiated by an automatic controller, such as an ECU. Action **911** may then be carried out, which is again de-energizing coil **119**. The actions of method **900** may subsequently repeat.

The components and features of the present disclosure have been shown and/or described in terms of certain embodiments and examples. While a particular component or feature, or a broad or narrow formulation of that component or feature, may have been described in relation to only one embodiment or one example, all components and features in either their broad or narrow formulations may be combined with other components or features to the extent such combinations would be recognized as logical by one of ordinary skill in the art.

The invention claimed is:

1. A valvetrain for an internal combustion engine of a type that has a combustion chamber, a moveable valve having a seat formed in the combustion chamber, and a camshaft, the valvetrain comprising:

a rocker arm assembly comprising a rocker arm and a cam follower configured to engage a cam mounted on the camshaft as the camshaft rotates;

an electromagnetic latch assembly comprising:

a latch pin configured to translate between a first position and a second position; and

a coil mounted on the rocker arm; and

an electrical circuit including the coil and an electrical connection made by abutment between a first surface belonging to a first part and a second surface belonging to a second part;

wherein the rocker arm assembly is operative to move the first surface relative to the second surface in response to actuation of the cam follower; and

wherein the electromagnetic latch assembly provides the latch pin with positional stability independently from the coil when the latch pin is in the first position and when the latch pin is in the second position.

2. The valvetrain of claim **1**, wherein the electromagnetic latch assembly comprises a permanent magnet fixed to the rocker arm.

3. The valvetrain of claim **2**, wherein:

the electromagnetic latch assembly forms a first magnetic circuit operative to be a primary path of magnetic flux from the permanent magnet when the latch pin is in the first position;

the electromagnetic latch assembly forms a second magnetic circuit, distinct from the first magnetic circuit, operative to be the primary path of the magnetic flux from the permanent magnet when the latch pin is in the second position; and

the permanent magnet contributes to the positional stability of the latch pin when the latch pin is in the first position and when the latch pin is in the second position.

4. The valvetrain of claim **3**, wherein:

the electromagnetic latch assembly further comprises a second permanent magnet fixed to the rocker arm; and

the second permanent magnet further contributes to the positional stability of the latch pin when the latch pin is in the first position and when the latch pin is in the second position.

5. The valvetrain of claim **3**, further comprising a controller configured to selectively energize the coil such that actuation of the latch pin is limited to times at which the cam is on base circle.

6. The valvetrain of claim **1**, further comprising circuitry operable to alternately energize the electrical circuit with a DC current of a first polarity and a DC current of a reverse polarity.

7. The valvetrain of claim **1**, wherein one of the first part and the second part is a contact pad.

8. The valvetrain of claim **1**, wherein one of the first part and the second part is a spring-loaded contact pin.

9. The valvetrain of claim **1**, wherein one of the first part and the second part is a leaf spring.

10. The valvetrain of claim **1**, wherein the second part is held by a contact frame that rests on a cylinder head.

11. The valvetrain of claim **1**, further comprising a controller configured to selectively energize the coil such that actuation of the latch pin is limited to times at which the cam is on base circle.

12. The valvetrain of claim **1**, wherein the rocker arm assembly is operative to slide the first surface over the second surface.

13. The valvetrain of claim **1**, wherein the coil is housed in the rocker arm.

14. The valvetrain of claim **1**, further comprising:

a lash adjuster configured to raise and lower the rocker arm assembly so as to adjust lash between the rocker arm assembly and the cam;

wherein the first surface slides over the second surface when the lash is adjusted.

15. A method of operating a valvetrain for an internal combustion engine of a type that has a combustion chamber, a moveable valve having a seat formed in the combustion chamber, and a camshaft; the valvetrain comprising a rocker arm assembly, an electromagnetic latch assembly, and an electrical circuit; the rocker arm assembly comprising a rocker arm and a cam follower configured to engage a cam mounted on the camshaft as the camshaft rotates; the electromagnetic latch assembly comprising a latch pin configured to translate between a first position and a second position and a coil mounted on the rocker arm; the electrical circuit comprising the coil and an electrical connection made by abutment between a first surface belonging to a first part and a second surface belonging to a second part; wherein the rocker arm assembly is operative to move the first surface relative to the second surface in response to actuation of the cam follower; and wherein the electromagnetic latch assembly provides the latch pin with positional stability independently from the coil when the latch pin is in the first position and when the latch pin is in the second position, the method comprising:

energizing the coil so as to actuate the latch pin from the first position to the second position when the cam is on a base circle;

raising the cam off the base circle so as to actuate the rocker arm assembly while the latch pin is in the second position;

energizing the coil so as to actuate the latch pin from the second position to the first position when the cam is returned to the base circle; and

raising the cam off the base circle so as to actuate the rocker arm assembly while the latch pin is in the first position.

16. The method of claim **15**, wherein the coil is de-energized when the cam is off the base circle.

17. The method of claim **15**, further comprising alternately holding the latch pin in the first position and the second position via at least one permanent magnet.

18. The method of claim **15**, wherein the first surface slides over the second surface when the cam is raised off the base circle.

19. A method of operating a valvetrain for an internal combustion engine of a type that has a combustion chamber, a moveable valve having a seat formed in the combustion chamber, and a camshaft; the valvetrain comprising a rocker arm assembly, an electromagnetic latch assembly, and an electrical circuit; the rocker arm assembly rocker arm assembly comprising a rocker arm and a cam follower configured to engage a cam mounted on the camshaft as the camshaft rotates; the electromagnetic latch assembly comprising a latch pin configured to translate between a first position and a second position and a coil mounted on the rocker arm; the electrical circuit comprising the coil and an electrical connection made by abutment between a first surface belonging to a first part and a second surface belonging to a second part; wherein the rocker arm assembly is operative to move the first surface relative to the second surface in response to actuation of the cam follower; and wherein the electromagnetic latch assembly provides the latch pin with positional stability independently from the coil when the latch pin is in the first position and when the latch pin is in the second position, the method comprising:

- energizing the coil so as to actuate the latch pin from the first position to the second position;
- rotating the cam while the latch pin is in the second position;
- energizing the coil so as to actuate the latch pin from the second position to the first position; and
- rotating the cam while the latch pin is in the first position;
- wherein the energizing of the coil is limited to times at which the cam is on a base circle.

20. The method of claim **19**, wherein the first surface slides against the second surface when the cam is raised off the base circle.

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